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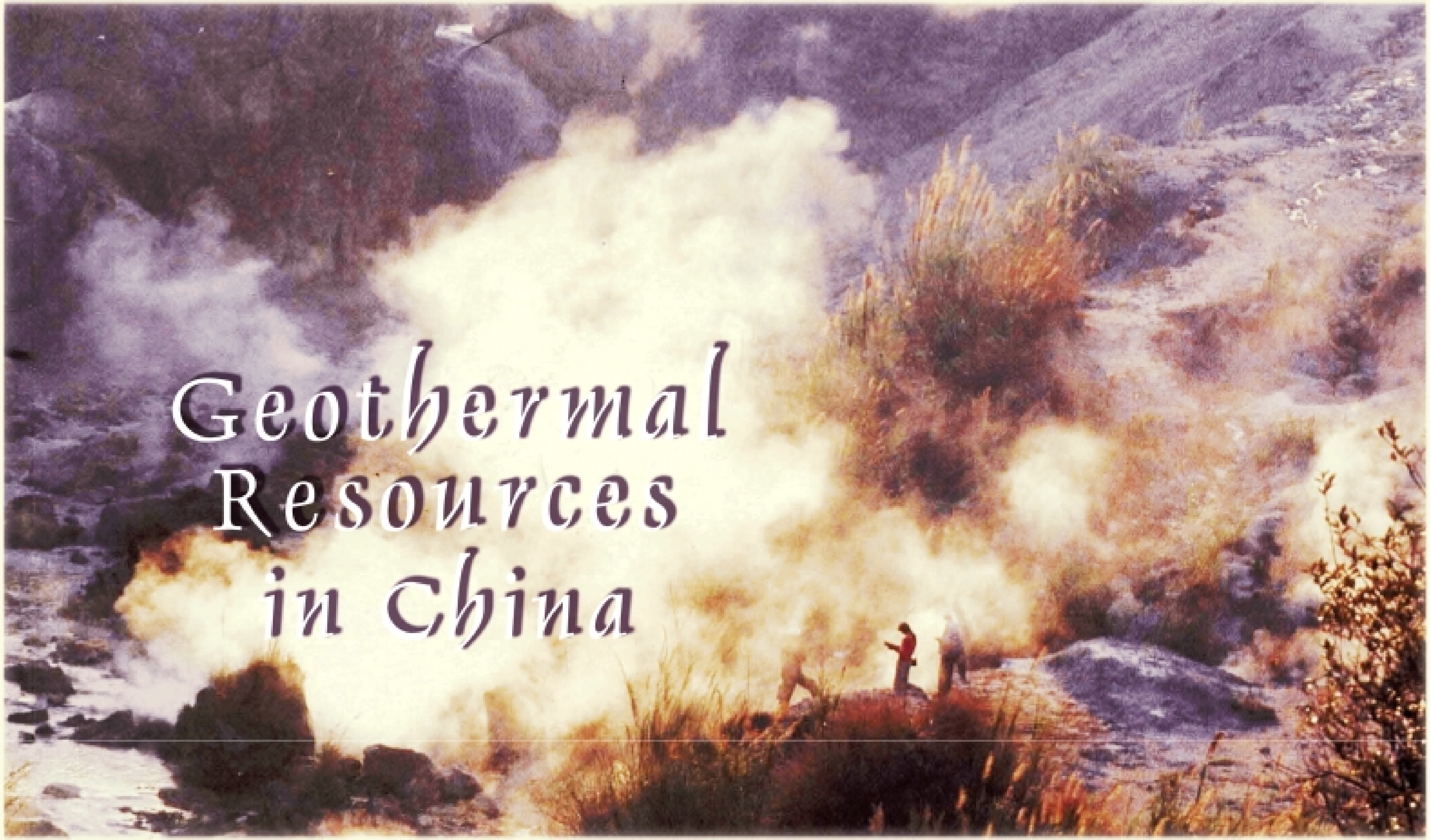

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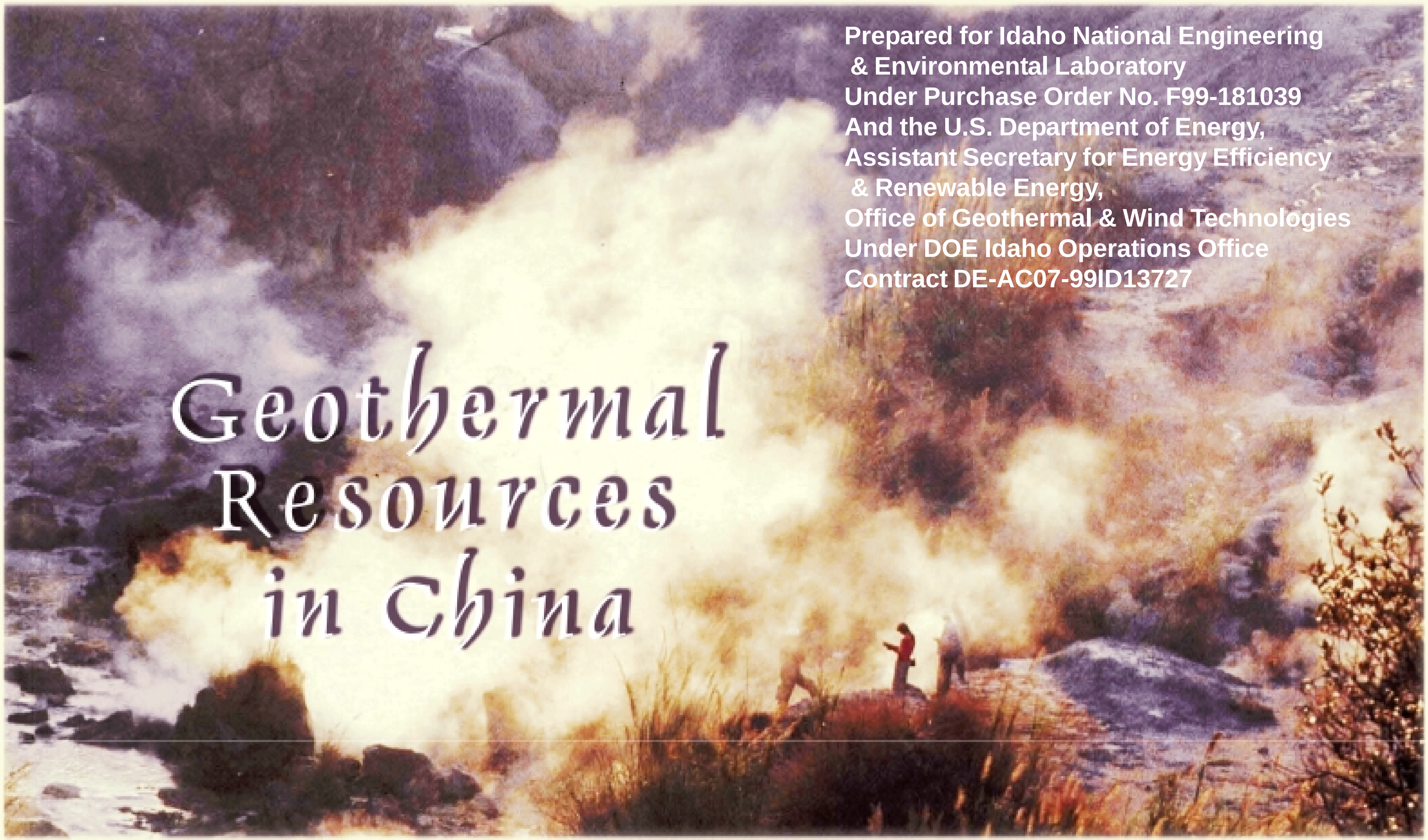

Geothermal Resources in China

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Table of Contents

Introduction

The **Database of Geothermal Resources in China** contains information on 254 specific geothermal sites in the People's Republic of China and 8 sites in Taiwan:

Country	Sites	Potential MWe	Potential MWt
People's Republic of China	254	1588.18	573
Taiwan	8	130	N/A *
Totals	**262**	**1718.18**	**573**

** N/A - Not available*

Actual figures are higher as specific potential data is not available for all sites.

The Database focuses on mainland China and Taiwan. Hong Kong and Macau, which reverted to Chinese sovereignty on July 1, 1997 and December 20, 1999 respectively, have no cited geothermal resources. It was compiled using data collected in an extensive information sweep which accessed technical literature dating back to 1979 as well as numerous other U.S. , Chinese, and Taiwanese sources.

China has 3,000 hot springs. This paper report focuses on 46 sites in China which have a measured or geothermometric temperature of 150ºC of more, and thus may be suitable for power generation; sites where power plants have been installed across China; and all 8 sites in Taiwan. For immediate dissemination to the industry, it has been converted to a PDF file.[1] The Microsoft® Access 2000 Database itself contains data on all 262 low-, medium-, and high-enthalpy sites on which information was collected.

The Database includes:

- Power Profile - basic information on China and Taiwan, e.g., population, installed capacity, power generation breakdown, electricity prices, etc.;

[1] PDF files can be read and printed using the free Adobe® Acrobat® Reader which can be downloaded at http://www.adobe.com/prodindex/acrobat/readstep.html).

- Power Summary - brief description of China's and Taiwan's power sectors and privatization efforts;
- Government / Legislation - relevant Chinese and Taiwanese government agencies and laws; and
- Geothermal Sites / Projects - includes a Site Summary for each:

    1. Name
    2. Location
    3. Status
    4. Temperature
    5. Installed Capacity (MWe/MWt)
    6. Potential (MWe/MWt)
    7. Chronology
    8. Notes

Dynamic Database

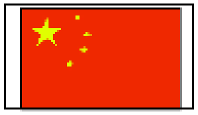
The Database was designed to be dynamic. Created using Microsoft® Access 2000, it can be easily updated or modified to include specific data which the industry would find most useful. In addition, the Database can be made more comprehensive by adding pertinent data, e.g., local population and market data, location of transmission lines and roads, etc., using the Geographic Information System (GIS) to the present structure. Finally, the Database could be adapted for posting on the World Wide Web and searched using a variety of variables such as country, desired temperature of resource, estimated power potential, and other parameters.

The Database of Geothermal Resources in China was compiled and built by Liz Battocletti and Zheng Li of Bob Lawrence & Associates, Inc. for Bechtel BWXT Idaho, L.L.C. (BBWI) under Purchase Order Number F99-181039, "Collection and Assembly of Published Data on Geothermal Potential."

Special appreciation goes to Joel Renner of Idaho National Engineering and Environmental Laboratory (INEEL); Allan Jelacic and Marshall Reed of the U.S. Department of Energy's Office of Geothermal and Wind Technologies; and the other individuals, companies, and organizations who provided assistance and information.

The photograph on the cover is a geothermal area in Tengchong County, Yunnan Province. The photo is reproduced from a study, *Geothermal Area in Tengchong Yunnan Province*, published by the Yunnan Provincial Science and Technology Commission in February 1996.

China



China

Power Profile

Population (millions) - July 1999 estimated	1,246.87
Overall Electrification (% of population)	94.8%
GDP (billion US$) - 1998 estimated	$4,420
Real GDP Growth Rate - 1998 estimated	7.8%
Inflation Rate (CPI) - 1998	-0.8%
Total Installed Capacity (MWe) - 1998	300,000
Electricity Consumption per Capita (kWh) - 1997	846.29
Energy Demand Growth Rate	4.5%
Prices (US¢/kWh) - 1999 - Beijing	
Residential	3.7
Commercial	6.2
Industrial	4.1

China is divided into 23 provinces (China considers Taiwan the 23rd), five autonomous regions, and three municipalities.

Power Summary

With 1.25 billion people, the People's Republic of China is the world's most populous country and second largest energy consumer (after the United States). If past trends continue, China's economy will become the largest in the world in this century.

Despite a sharp decline in 1998 partly as a result of the Asian financial crisis, energy demand has doubled since 1980 and could triple in the next 20 years (U.S. Department of Commerce, 2000). Yet approximately 65 million Chinese do not have access to electricity[2], and one-third of households in China are not yet connected to electricity grids (Blackman and Wu, 1997). Per capita electricity consumption is low. The country has a glut of electricity in the coastal areas, but transmission systems

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2 Remarks by Dongrong Ye, Beijing Jike Energy New Technology Development Co. at the U.S.-China Renewable Energy Forum; April 20, 2000; Arlington, VA.

and development in the interior, particularly in the western part of the country, require continued investment.

The power sector is undertaking large-scale technical renovations designed to control pollution, increase financial returns, and guarantee safe operations. Generating units which are 25 years old and up are being renovated. The goals are to improve the capacity of the units to meet peak power demands, improve security, reduce energy consumption, and protect the environment.

Currently, China's electric power industry is experiencing an oversupply problem, due in part to slower Chinese economic growth as a result of the Asian economic crisis.

As of the end of 1998, China had an installed capacity of approximately 300 GWe of which 75% was thermal, 23% hydroelectric, less than 2% nuclear, and the balance renewable and other. China is expected to double its installed capacity to 600 GWe by 2015, adding an estimated 300 GWe of generating capacity over the next 15 years. China's ambitious energy program will require $200-300 billion in capital investment. Much of the technical expertise and capital are expected to come from foreign sources.

China faces numerous challenges in meeting its energy needs:

- relatively high energy intensity;
- extreme air pollution (five of the world's 10 most polluted cities are in China);
- a resource base far from consumption centers resulting in the need to expand the pipeline and distribution network;
- large and inefficient state-owned enterprises (SOEs) which still dominate the energy sector;
- 60-80 million people in rural areas with no access to electricity;
- rising oil imports;
- an inefficient and relatively unconnected electric grid resulting in generation losses of 20%; and
- the need to mobilize investment estimated at US$1 trillion from now until 2020 for energy expansion, of which 20% will come from foreign investment (U.S. Department of Commerce, 2000).

China's energy strategy is designed to address these challenges by decreasing reliance on coal, increasing petroleum exploration and development, enhancing efficiency and environmental protection, increasing development of hydro and nuclear power, and developing rural electrification and renewable energy resources. This energy strategy is being implemented against a backdrop of the major restructuring of government and state entities, a process which was launched in March 1998 and is still evolving (U.S. Department of Commerce, 2000).

China is the world's largest producer and consumer of coal which is presently the country's predominant source of energy, accounting for 75% of the energy for power generation. Coal will remain critical to China's energy mix for the next 50 years, Environmental impacts from the use of coal with current Chinese technology are severe. If China's economy continues to grow at the rate it has since 1980— approximately 10% per year — it will pass the United States to become the leading source of CO_2 emissions by 2050.

The Chinese Government has recognized the problem of environmental impacts resulting from energy development, and has developed a strategy for future sustainable development, involving the widespread use of Clean Coal Technologies and increased development of oil, natural gas, and coal bed methane resources.

Natural gas's share of total energy production is expected to grow to about 4.1% by 2015, as China begins to take greater advantage of its large domestic reserves (China has an estimated 26 trillion cubic meters of natural gas resources).

Although China's exploitable hydro reserves, estimated at 380 GWe, are considered the world's largest, they are presently too expensive to develop. By one estimate, only 10% have been developed (Tunnah 1994; Dorian, 1995). The bulk of China's hydro reserves are located in the western and southern regions (Blackman and Wu, 1997).

The Three Gorges project on the Yangtze River involves construction of the world's largest dam, with 26 hydropower generating units (700 MWe each) slated to provide a total of 18 GWe generating capacity by 2009. China currently has more than 50,000 small hydropower stations scattered across the country.

As for wind power, China has identified sites with a total potential of 3,000-8,000 MWe. Over 200,000 mini and small wind generators have been installed in households in mountain areas, remote rural areas, and islands. Current financial returns on wind farm development are too low to attract large-scale utility or independent power producer (IPP) investment (Taylor and Bogach, 1998).

High-temperature geothermal resources are primarily located in Tibet, western Yunnan, and western Sichuan provinces — remote areas where conventional energy is limited, and the population is low. Small geothermal plants have played and will continue to play an important role in those areas (Ren et al., 1995).

Estimates of power generation potential range from 200-500 MWe (Allis et al., 1996) to over 10,000 MWe (Zhijie, 1997).

With support from the World Bank, the United Nations Development Programme (UNDP), and foreign governments, China is promoting the widespread commercialization of renewable energy technologies, primarily wind and solar.

UNDP and the Global Environment Facility (GEF) have launched the "Capacity Building for the Rapid Commercialization of Renewable Energy" program. In addition to helping create the Chinese Renewable Energy Industries Association (CREIA), the program will also activities in business development and financing, standards and certifications, renewable resource database and GIS development, technical assistance for wind power development, and study tours. The $26.7-million program focuses on biogas, wind, photovoltaics (PV), and bagasse co-generation.

The $444-million World Bank Renewable Energy Development Project supports the development of the two most promising renewable energy technologies, grid-connected windfarms and solar PV for rural applications. Specifically, the project will provide 10 MWp of PV systems to households and institutions in remote areas of six northwestern provinces, and 190 MWe of grid-connected windfarms in Inner Mongolia, Hebei, Fujian, and Shanghai provinces.

The U.S. Export-Import Bank (EXIM) supports the export of U.S. goods and services for projects involving renewable energy and energy efficient technologies to China through the $100-million Clean Energy Program facility. Projects eligible for inclusion are: wind, solar, and geothermal technologies; industrial co-generation: energy efficient buildings; and low NOx and SOx burners. Financing is available for commercial projects with competitive financing rates. The State Planning Commission must approve the project; the China Development Bank is the borrower.

The Overseas Private Investment Corporation (OPIC) suspended its programs in China following the Tiananmen incident in June 1989, and will remain suspended in China subject to U.S. foreign policy concerns, the terms of the sanctions legislation enacted, and improvements in worker rights conditions.

Government / Legislation

Nicknamed the "Power Tiger" because it could act as it pleased, despite customer complaints, China's power sector has been, and continues to be, under State control. Although China's energy sector is currently being "corporatized,"[3] the Chinese Communist Party (CCP) still dominates the entire political apparatus, and its leaders make all major policy decisions.

Party members hold most senior government positions at all levels of administration. Ministries and lower-level counterparts implement policy on a day-to-day basis, and China's parliament, the National People's Congress (NPC), reviews and approves legislation and nominees for government offices.

Many provincial governments — especially those in fast-growing coastal regions— actively adapt central government policy decisions to suit local needs. Senior leaders generally agree on the need for further economic reform, but stability is still a paramount concern, and there remain differences within the leadership over the content, pace, and goals of reform.

Beginning in the mid-1980s, the Chinese government implemented a number of structural and pricing reforms in the power sector, halting its practice of giving direct investment "grants" to power projects in favor of granting loans through banks and other financial institutions. Replacing the practice of exclusive central government funding led to expanded domestic (local government, industrial sector, and enterprise) and foreign funding of power projects. The government furthermore allowed projects to price electric power to reflect the cost of financing. The government took further steps in 1997 to reform electricity pricing (Wang, 1999).

Generation is being separated from transmission and distribution, and proposed new generation is expected to yield an adequate return on investment (Hood and Sweet, 1999). The operation of power plants and distribution will be separated by 2010.

Central government agencies that are involved in developing and implementing China's energy and renewable energy are:

- State Power Corporation of China (SPC or SPCC)
- State Development Planning Commission (SDPC)
- State Economic and Trade Commission (SETC)
- Ministry of Science and Technology (MOST)
- Ministry of Geology and Mineral Resources (MGMR)
- Ministry of Agriculture (MOA)

3 Government officials are reluctant to use the word "privatize" given the critical role the State is supposed to play in all industrial activities; the term "corporatize" is more readily acknowledged (Dorian, 1998).

Coordination between these groups is good. Not as effective is the coordination among the wide variety of research institutions and government agencies at the provincial and local levels.

State Power Corporation of China (SPC or SPCC)

SPC was established as a corporation solely owned by the State Council in 1995-96 to handle the business functions formerly situated in the Ministry of Power Industry (Mopi). Modeled after France's Electricité de France and the State Corporation of Italy, the semi-autonomous SPC supervises electricity generation, transmission, and distribution. SPC also solicits foreign investment and engages in international cooperation.

SPC is responsible for long-term planning, including five-year plans, development of new capital projects, and project financing and approval. It must approve and finance, in general, any large project involving more than $10 million worth of investment (Dorian, 1998).

SPC's primary functions are to invest in, build, and operate power projects; serve as monopoly operator of China's power transmission and distribution system until at least 2010; and implement the "unified dispatching of power grids." SPC is in effect a giant power-producing utility, comparable in scope and even technical sophistication to Electricité de France or Hydro Québec (Sweet and Bretz, 1999). SPC operates and manages 140 GWe of installed capacity (Dorian, 1998).

The creation of SPC was the first step in China's "Four-Step Strategy for Power Industry Management Restructuring"[4]:

- *Phase I (1997-1998)* – Structural separation of business and governmental functions. Creation of SPC. Elimination of the Ministry of Electric Power.

- *Phase II (1998-2000)* – SPC establishes new nationwide infrastructure. Continued separation of business and government functions.

- *Phase III (2001-2010)* – Unification of the nationwide grid. Moving to single buyer model[5] (producers compete on price to sell

4 The reformed structure discussed is the intended structure. Both governmental and business functions largely still remain with the old Ministry of Electric Power personnel, who are now mostly part of the new SPC (Wang, 1999).

5 In the "single-buyer," generation competition stage, SPC, which produces more than one-third of China's total power output, will be in competition with IPPs. In times of surplus, SPC as

to the grid). SPC manages the grid. Generation component to be unbundled from transmission and distribution ("networks shall be separated from power plants, [and an] orderly competed (sic) power market shall open to all power plants") (Wang, 1999).

- *Phase IV (2010-2020)* – Achievement of market system "approximate to international advanced level." Grid management transferred from SPC to government side.

State Development Planning Commission (SDPC)

SDPC, formerly known as the State Planning Commission, formulates the National Economic Development Plan, the Five-Year Plan, and the National Long-Term Program. SDPC also approves all project investments. The Department of Basic Industries under SDPC is responsible for energy and electric power development strategy, medium and long-term planning, and overall planning for large energy projects.

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grid operator, could favor electricity produced by its own facilities even if it is not the lowest cost provider (Wang, 1999).

The Foreign Capital Utilization Department approves joint ventures and foreign-funded projects in China, and allows the conversion of Chinese currency into hard currency.

The Department of Product Pricing Management approves electricity prices. The Department of Price Supervision is responsible for enforcement of approved prices.

According to a senior SDPC official, China is paying close attention to geothermal energy resources and plans to build medium-sized geothermal power plants in the southwestern part of the country. The power plants will be built in Tibet and western parts of Yunnan and Sichuan provinces by 2020. Priority will be given to geothermal resources in Yangbajian which have reservoir temperatures of over 200ºC. The country will build smaller plants of 3-5 MWe in Ruili in western Yunnan province. Geothermal resources in Tengchong will be studied (Xinhua, 1998).

State Economic and Trade Commission (SETC)

SETC's responsibilities in the electric power industry include power sector planning, industry policy formulation, approval of sectoral standard, drafting of laws and regulations, general industry supervision, and improving rural electricity supply. In addition, SETC approves technology transfer projects.

The Energy Division of the Energy Conservation and Comprehensive Utilization Department formulates the Government of China's (GOC) renewable energy policies and regulations. This division promotes new renewable energy development and organizes environmental protection development and projects associated with environmental protection. In addition, the division controls millions of Yuan Renminbi (RMB) to be used for loans towards renewable energy project development.

Ministry of Science and Technology (MOST)

Formerly known as the State Science and Technology Commission (SSTC), MOST oversees national science and technology research projects. The High and New Technology Development and Industrialization Department is responsible for regulating and organizing science and renewable energy technology projects. MOST and SDPC jointly formulate the Five-Year Plan for science and technology. MOST also organizes and implements renewable energy research projects and promotes its technological institutions.

Through its National Geothermal Development Center, MOST administers all research activities related to geothermal resources, and is also responsible for prioritizing prospective resource development activities and relaying this information to the Ministry of Geology and Mineral Resources, Beijing University, the Chinese Academy of Sciences, and Tianjin University have executed research projects for SSTC.

Ministry of Geology and Mineral Resources (MGMR)

Geothermal resource development activities, e.g., drilling, production tests, interference tests, are MGMR's responsibility. In addition to the central organization, there are also province- and county-level geology and mineral bureaus.

Ministry of Agriculture (MOA)

The Energy Division of MOA, which oversees rural environmental and electrification issues, grants 10 million Yuan RMB (approximately US$1,200,000) each year to support renewable energy technology dissemination and demonstration projects, with emphasis on biomass and solar/thermal technologies.

China first allowed foreign investment in the power industry in 1984. Foreign investment accounts from 10-20% of the industry's total investment, according to the State Power Corporation, attracting $20.7 billion since 1984.

Since 1993, the Chinese Government has made significant strides in opening the power sector to foreign investment, technological assistance, and global trade.

Several central government laws, policies, and regulations affect energy and renewable energy development throughout China. Many provinces have their own incentives and laws in addition to those enacted by the government in Beijing.

Electricity Law – April 1996

China's Electricity Law provides a comprehensive legal framework for the development of the country's power industry. It supports the role of foreign investment and addresses direct investment in power plants through joint ventures or foreign-owned companies, and ensures that investments are in line with China's national industrial policies and long-term economic development plans.

The Law also stipulates that electricity prices shall reasonably compensate for production costs and rates of return and take into account applicable taxes. The law does not provide any guidance on what constitutes a reasonable rate of return. Pricing for electricity in rural areas will be determined on the basis of cost recovery plus a minimal level of profit.[6]

[6] The GOC imposes (though not officially) a ceiling on the return on equity to power projects of 15-18% (Dorian, 1998). There are ways of getting around this "invisible cap on returns" but it usually involves more time and bureaucracy (Vaupen, 1999).

The GOC has made favorable policies in China's Electricity Law for purchasing power from renewable energy projects. The following provisions are stated:

- Provisions 5, 48: Renewable energy is strongly encouraged by the state.
- Provision 22: Stipulates that the state power utility, which is in charge of the local power grid, must purchase electricity generated by IPPs.
- Provision 36: Stipulates that the price paid for electricity should cover the cost to produce the electricity and that the returns should be reasonable in order to promote electric power development.

Build-Operate-Transfer (BOT) Law

China encourages foreign investors to be involved in the construction of infrastructure projects by using such methods as BOT and project financing.

The present regulations in China allow for either foreign ownership of up to 49% or 100% of share capital of a BOT company. This regulation prevents any foreign investor from having a controlling share in the project company unless it owns 100% of the BOT enterprise. Under such a ruling, many potential foreign investors have been reluctant to consider undertaking large BOT projects because of the limited control they would enjoy (Dorian, 1998).

The application of BOT in China is carried out stage by stage. The procedures for establishing a BOT project are as follows:

- The project sponsor prepares the project proposal, and submits it, using the required procedures, for project approval;
- Once the project is approved, the government authority sponsoring the project organizes or entrusts an agency to prepare the bid invitation documents including the concession agreement, and continuing with the bid invitation and submission activities for selecting the foreign partner;
- The concession agreement as approved by the government body sponsoring the project is attached to the project feasibility study report prepared by the selected bidder and the appraisal report by the bid selection committee;
- Once the project concession agreement is approved, the bid winner[7] must, within the required period, establish the project company in accordance with procedures specified in the law governing foreign investment; and
- The government authority shall officially sign the concession agreement with the project company, and the agreement will be effective immediately upon being signed.

All foreign investment projects must be approved by the Ministry of Foreign Economic Relations and Trade (MOFERT) and the State Administration of Exchange Control (SAEC). Projects smaller than 150 MWe or costing less than $30 million more can bypass central government approval. SDPC must approve all BOT projects over $30 million; the State Council must approve those exceeding $100 million.

Ninth Five-Year Plan (1996-2000)

In the Ninth Five-Year Plan (1996-2000), China adopted several ambitious national programs including the

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7 The practice of BOT in China is conducted through competitive conditional bidding. Once the project proposal is approved, the bidding procedure begins.

"Brightness Program," "Integrated and Comprehensive Rural Electrification," "Energy Efficient Lighting," and "Riding the Wind Program." In addition, China is implementing the Energy Conservation Law which was adopted by the People's Congress on November 1, 1997. All of those programs and policies are designed to use efficiency and renewable energy as a means of reducing energy intensity (the energy used to produce a unit of Gross Domestic Product) and provide least-cost electricity to remote areas, thus curtailing environmental damage (Protocol Progress Report, 1999). During the Ninth Five-Year Plan, 90% of rural Chinese homes will reportedly have electricity.

Tenth Five-Year Plan (2001-2005)

In the Tenth Five-Year Plan (2001-2005), China will pay great attention to developing renewable energy, especially on improving its conversion efficiency, cutting production costs, and increasing its share in national energy construction. In particular, China will implement the "Strategy Plan for Developing the West Area of China." Renewable energy will have an important role to play in bringing electricity to this sparsely populated region of China (Shi, 2000).

The Tenth Five-year Plan's objective vis-a-vis geothermal is, by 2005 to:

- have geothermal energy, including power generation and direct use, account for 1 million tons of Mtce (million tons of coal equivalent, equal to 0.12276 TWh of electricity);
- build a 10 MWe geothermal demonstration plant in Tengchong County; and
- develop geothermal heat pump technology from application to commercialization.

"Same Grid, Same Price"

China experimented with energy price reform in controlled stages for much of the 1980s and early 1990s.

The GOC often used a multi-tiered pricing system – one for energy production within the state plan; another, higher level for production which exceeded state plans. More extensive reforms in the early 1990s resulted in rapidly rising energy prices.

Regional overcapacity, common in the late 1990s, resulted in some power purchase agreements not being honored as old plants, which have already recovered their capital costs, can supply power most cheaply (Logan. 1999). Average prices have stabilized since the late 1990s as supply exceeded demand (Logan, 1999).

The GOC recently established new “same grid, same price” policies – all plants connected to the same regional grid must charge the same price for electricity. As a result of the heavily-subsidized and costly Three Gorges Dam project, however, Chinese electricity prices will be distorted for a long time as a major source of electricity is massively subsidized by the government (Wang, 1999).

China’s accession to the World Trade Organization (WTO) will dramatically broaden competition within China which will demand that power be sold at competitive prices (David Hartman, U.S.-China Renewable Energy Forum, April 20, 2000).

<u>“New and Renewable Energy Development Program, 1996-2010"</u>

The “New and Renewable Energy Development Program, 1996-2010" is designed to improve the efficiency of renewable energy technologies, lower production costs, and increase renewable energy’s contribution to the country’s energy supply within a market system.

Despite their proven environmental and social benefits, renewable energy in China remains largely undeveloped for several reasons — limited capacity to disseminate renewable energy through market mechanisms, institutional fragmentation, lack of business skills, incomplete assessment of renewable resources, lack of facilities for testing and certifying equipment, high cost of renewable energy systems, and lack of suitable funding mechanisms.

The details of the program are as follows:

- Renewable energy mainly includes wind power, PV, biomass power, geothermal power, and ocean energy. The State Planning Commission and Ministry of Science and Technology will actively support the projects concerning renewable energy for power when arranging construction, as well as scientific projects financed by the state government.

- Renewable energy power projects have priority in getting loans for capital construction, with the State Development Bank granting loans to such projects. The State Planning Commission will aid the developers of those projects which are approved by the State, and have a capacity of over 3,000 kWe, to obtain bank loans. The projects, which get loans from banks, will get 2% interest deducted. The Ministry of Finance will pay the deducted interest for the state projects. The borrower should meet the following requirements:

  1. The project developer will obtain a letter of intent for bank loans when preparing a

project proposal, and a letter of commitment when doing the feasibility study.

2. The equity of the project on renewable energy for power will not be lower than 35% of the total project investment.

3. The developer will pay the loan interest to the bank, and apply to the financial department for interest deduction on an annual basis.

- For renewable energy electric power projects, the electric grid management department will purchase all power and allow the nearest grid connection. The legal representative of the project will get a PPA from the utilities and a letter of intent for grid connection when preparing the project proposal, and a letter of commitment when conducting the feasibility study.

- When the project is still within the loan payback period, the pricing will follow the principle of repayment plus related interest plus reasonable profit. The amount that exceeds the grid average power price will be shared within the electric grid. The investment profit rate of a project which uses imported equipment will not exceed 3% plus the interest rate on the loan. Due to the local production encouragement policy, the investment profit rate of projects using Chinese-built equipment will not be lower than 5% plus the interest rate.

- The power price of projects using Chinese-made equipment will be equal to the power price of the projects using imported equipment and connected to the same grid.

- At the project proposal stage, the developer will obtain a letter of intent for the power purchase price from the local Price Bureau. At the feasibility study stage, the local Price Bureau will examine the power price (including the price constitute), and report to the State Planning Commission for the record. The power purchase price approved by the local Price Bureau and the State Planning Commission will come into effect at the project starting date. After the loan payback period, the price will be set according to the electric grid's average power price.

- The government encourages adopting lease contract or installment payments to develop stand-alone renewable energy power systems. The local government stipulates specific rules according to the local factual conditions, and reports to the State Planning Commission for the record.

- The explanation of the provisions of this document is subject to the State Planning Commission.[8]

Regulations on the Development and Application of Geothermal Resources, October 1989

China's geothermal law governs the exploration and application of the country's geothermal resources. Provincial and county-level regulations may also apply.

At the national level, SETC's objectives regarding geothermal development are to:

- Use high-enthalpy geothermal resources for power generation in remote areas of China,
- Greatly develop low and medium-enthalpy geothermal resources for heat supply and comprehensive utilization, and
- Improve the level of geothermal equipment production (Zhai, 2000).

The goal is to have 30 MWe of installed power generation capacity from geothermal resources by 2000, 40-50 MWe by 2005, and 75-100 MWe by 2010 (Zhai, 2000).

Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Development and Utilization

On February 25, 1995, the U.S. Department of Energy (DOE) and the State Science and Technology Commission, now MOST, signed a "Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Development and Utilization."[9]

Annex VI to the Protocol, "Cooperative Activities on Geothermal Production and Use," was signed on November 18, 1997 between the State Science and Technology Commission (now MOST) and DOE. The objective of this agreement is to accelerate the utilization of geothermal resources in China, both for electricity generation and direct thermal energy use.

8 For more information on the "New and Renewable Energy Development Program, 1996-2010" see http://ntwebsrv1vh1.nrel.gov/international/china/whats_new.html.

9 For more information on the Protocol, see http://ntwebsrv1vh1.nrel.gov/international/china.

In Fall 1998, DOE sent two U.S. geothermal experts to Tengchong County to work with the Chinese drilling team to look at drilling equipment, safety, and geological issues and make recommendations for their improvement.

In addition, DOE will supply technical assistance in feasibility studies and training to support China's efforts to demonstrate geothermal heat pump (GHP) technology in three commercial buildings, using U.S.-made equipment.

Finally, through the Lawrence Berkeley Laboratory, DOE is supporting a scientific study of the geological mechanisms that are producing the geothermal energy resources at the Tengchong site.

Political, 1996

University of Oregon, http://darkwing.uoregon.edu/~felsing/cstuff/cmaps.html

Shaded Relief, 1996

University of Oregon, http://darkwing.uoregon.edu/~felsing/cstuff/cmaps.html

China: Administration

Province-Level Names

Characters	Pinyin	Pronunciation	Characters	Pinyin	Pronunciation
安徽	Anhui	an-hway	辽宁	Liaoning	lee-ow-ning
北京	Beijing	bay-jing	内蒙古	Nei Mongol	nay-mung-goo
福建	Fujian	foo-jee-en	宁夏	Ningxia	ning-shee-ah
甘肃	Gansu	gahn-soo	青海	Qinghai	ching-hi
广东	Guangdong	gwang-doong	陕西	Shaanxi	shan-shee
广西	Guangxi	gwang-shee	山东	Shandong	shahn-doong
贵州	Guizhou	gway-joe	上海	Shanghai	shahng-hi
海南	Hainan	hi-nan	山西	Shanxi	shahn-shee
河北	Hebei	huh-bay	四川	Sichuan	suh-chwan
黑龙江	Heilongjiang	hay-loong-jee-ahng	天津	Tianjin	tee-en-jin
河南	Henan	huh-nan	新疆	Xinjiang	shin-jee-ahng
湖北	Hubei	hoo-bay	西藏	Xizang	shee-dzong
湖南	Hunan	hoo-nan	云南	Yunnan	yu-nan
江苏	Jiangsu	jee-ahng-soo	浙江	Zhejiang	juh-jee-ahng
江西	Jiangxi	jee-ahng-shee			
吉林	Jilin	jee-lyn	台湾	Taiwan	tie-wan

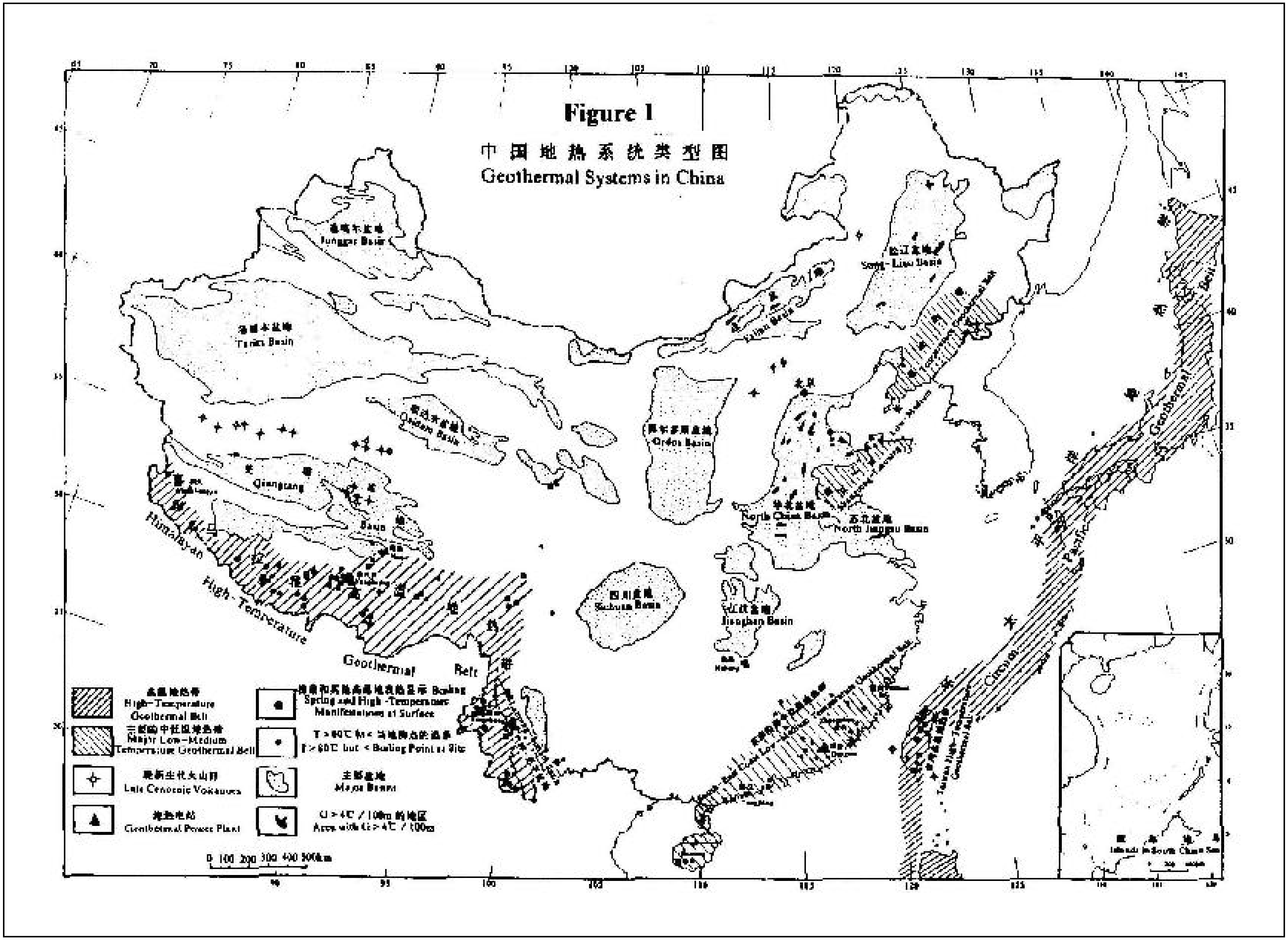


Figure 1
中国地热系统类型图
Geothermal Systems in China
Junggar Basin
Tarim Basin
Qaidam Basin
Qiangtang
Ordos Basin
Song-Liao Basin
North China Basin
North Jiangsu Basin
Sichuan Basin
Jianghan Basin
Himalayan High-Temperature Geothermal Belt
Circum-Pacific Geothermal Belt
High-Temperature Geothermal Belt
Major Low-Medium Temperature Geothermal Belt
Late Cenozoic Volcanoes
Geothermal Power Plant
Boiling Spring and High-Temperature Manifestations at Surface
Major Basins
0 100 200 300 400 500km

GEOTHERMAL RESOURCES > 150ºC AND SITES WITH POWER PLANT(S) IN CHINA

Project Name	Status	From Temp ºC	To Temp ºC	Installed capacity (MWe)	Potential (MWe)
Balazhang	Preliminary identification/report	98	214	0	Unknown
Bangbie	Preliminary identification/report	63	177	0	Unknown
Bongbeng	Preliminary identification/report	95	205	0	Unknown
Caojian	Preliminary identification/report	61	170	0	Unknown
Chaluo	Preliminary identification/report	88	220	0	10
Dakongbeng	Preliminary identification/report	97	212	0	11
Daping	Preliminary identification/report	94	180	0	Unknown
Dengwu	Power plant(s) on site	87	94	0.866	0.866
Eryuan	Preliminary identification/report	69	204	0	Unknown
Fengshun	Power plant(s) on site	95	N/A	0.5	0.5
Heishehe	Well(s) or hole(s) drilled	125	200	0	23.9
Huailai	Power plant(s) on site	85	88	0.2	0.2
Hui-Chang Spa	Power plant(s) on site	91	N/A	0.3	0.3
Huitang	Power plant(s) on site	88	102	0.03	0.03
Humeng	Preliminary identification/report	94	172	0	Unknown

Project Name	Status	From Temp ºC	To Temp ºC	Installed capacity (MWe)	Potential (MWe)
Jiangsi Yichune	Power plant(s) on site	67	N/A	0.05	0.05
Langjiu (Shiquanhe)	Power plant(s) on site	78	180	2	3.2
Lanniba	Preliminary identification/report	93	157	0	Unknown
Lanpu Hot Pool	Preliminary identification/report	96	220	0	Unknown
Lincang Hot Pool	Preliminary identification/report	64	177	0	Unknown
Litang	Preliminary identification/report	190	220	0	10
Longmadong	Preliminary identification/report	84	195	0	Unknown
Longwozhai	Preliminary identification/report	96	173	0	Unknown
Malutianba	Preliminary identification/report	96	178	0	Unknown
Mangwoshan	Preliminary identification/report	89	189	0	Unknown
Manzhao	Preliminary identification/report	97	202	0	Unknown
Maolan	Preliminary identification/report	68	152	0	Unknown
Maomaolei	Preliminary identification/report	70	196	0	Unknown
Mengman	Preliminary identification/report	99	234	0	Unknown
Mengping	Preliminary identification/report	102	180	0	Unknown
Naqu	Power plant(s) on site	62	170	1.3	5.73
Niujie-Sanying	Well(s) or hole(s) drilled	82	193	0	Unknown
Panzhihua Boiling Springs	Well(s) or hole(s) drilled	97	187	0	49.4
Quanqiaohe	Preliminary identification/report	96	190	0	Unknown
Rehai (Hot Sea)	Concession	97	275	0	233.5
Reli	Preliminary identification/report	215	227	0	19.8

Project Name	Status	From Temp ºC	To Temp ºC	Installed capacity (MWe)	Potential (MWe)
Renzhou	Power plant(s) on site	77	N/A	0.1	0.1
Reshuitang	Preliminary identification/report	145	221	0	96
Ruidian	Well(s) or hole(s) drilled	86	200	0	47.2
Ruili	Well(s) or hole(s) drilled	215	230	0	3
Wana	Preliminary identification/report	88	154	0	Unknown
Wentang	Power plant(s) on site	66	70	0.1	0.1
Xiabiaoyuan Xiaotang Spring	Preliminary identification/report	25	156	0	Unknown
Xiamiandian	Preliminary identification/report	71	170	0	Unknown
Xiangzhou	Power plant(s) on site	N/A	N/A	0	Unknown
Xiaodingxi-Xiaojie	Preliminary identification/report	94	207	0	Unknown
Xiaojie-Manbeng	Preliminary identification/report	101	175	0	Unknown
Xingfu	Preliminary identification/report	95	221	0	Unknown
Xiongyue	Power plant(s) on site	72	85	0.2	0.2
Yangbajian	Power plant(s) on site	125	330	25.18	900
Yangyi	Well(s) or hole(s) drilled	150	207	0	30
Yichun	Power plant(s) on site	N/A	N/A	0.1	0.1

Project Name	Status	From Temp ºC	To Temp ºC	Installed capacity (MWe)	Potential (MWe)
Yili	Preliminary identification/report	160	180	0	Unknown
Yongxin	Preliminary identification/report	97	158	0	Unknown
Yulingong	Preliminary identification/report	135	170	0	Unknown
Yunnancheng	Preliminary identification/report	99	166	0	Unknown
Zhaizhipo	Preliminary identification/report	50	165	0	Unknown
Zhaoyuan	Power plant(s) on site	90	120	0.2	0.2
TOTALS				**31.126**	**1445.376**

Geothermal Sites / Projects

China is located in the southeastern corner of the Eurasian Tectonic Plate. It is influenced both by the Pacific Plate to the east and the Indian-Australian Plate to the south. Two geothermal belts are formed at the juncture of these plates — the Himalayan Geothermal Belt and the Circum-Pacific Belt.

The Himalayan Geothermal Belt, which is the eastern extension of the Mediterranean Belt, passes through southern Tibet and western Sichuan Provinces, turns southward through western Yunnan Province and then extends downward through Thailand. In China, the Himalayan Belt is more than 2,800 km long and 200-400 km wide. The Circum-Pacific Belt passes through eastern Taiwan (Taylor and Li, 1996).

The geothermal background in China is closely related to tectonic factors. Generally the younger and more active regions have the highest geothermal background. Overall the heat flow pattern in China is characterized as high in the south and east and low in the west and north. For example, southern Tibet, western Sichuan and Yunnan, and Taiwan are active tectonic areas from the Cenozoic Age. The reason for these geographical disparities is that since the Mesozoic Age, China has been strongly influenced by the tectonic forces from the south and east mentioned above, creating hot regions in these areas (Taylor and Li, 1996).

China has 3,000 hot springs, including 2,200 springs with recorded temperatures of over 25ºC. Hot spring manifestations are located in more than 75% of the country's territory (Huang et al., 1981) — Tibet has 709, western Sichuan 342, and western Yunnan 694. Other provinces rich in thermal springs are Guangdong with 257, Fujian with 174, and Hunan with 109 (Zhijie, 1997).

Low and Medium-Enthalpy Resources

There are intermediate-low temperature resources at more than 2,900 sites with natural heat flow of 1.04 x 1014 kJ/yr, equivalent to 3.6 million tons standard coal per year. They are mainly located along China's southeastern coast in Guangdong, Fujian, and Hainan Provinces, and in some inland basins, including Song-Liao, North China, Jiang-han, etc. Thermal waters with temperatures of 80-120ºC are found at 1000-3000 m depth (Zhenguo, 1999).

China has used low-enthalpy geothermal resources for more than 2,000 years. Hot springs were used for irrigation and domestic purposes as early as in the Eastern Zhou Dynasty (c. 770-256 B.C.) (Yang, 1985). During the Han Dynasty, salt was extracted from thermal water in the Zigong area of Sichuan Province. In the Ming Dynasty, Li Shi-zheng, a famous medical doctor at the time, used hot spring water for treating diseases (Wang, 1995).

Today, China is one of the largest users of non-electric geothermal energy in the world with 1,620 sites across the country where geothermal energy is used for direct use. In total, these sites have produced energy equivalent to burning 5 million tons of standard coal. Sites in operation include: 112 sites for agricultural uses, 51 industrial applications, 65 sites using thermal springs for tourism and bathing, and 35 seismic observation stations (Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy, Progress Report, 1999). Direct uses amount to more than 2,000 MWt (Ishikura et al., 1999).

China has 24% of the world's geothermal heating applications. Low and medium enthalpy resources are primarily located in the inland and coastal areas of the country where population densities are high and the demand growing. Most of the work in this area has been carried out by Tianjin Geothermal Center.

Space heating is a common application in northern China where geothermal resources with temperatures of 40-80ºC provide heat to over 1.3 million m^2 of floor space. The largest project is in Tianjin where about 50 wells provide thermal water with temperatures up to 970 C to heat a total area of 805,000 m^2. Space heating projects in Beijing are spread over a large area of the city, although there are no large central heating systems (Taylor and Li, 1996).

The use of geothermal resources in China has grown 12% per year in recent years. As of 1999, 3,000 geothermal wells have been drilled in 70 cities.

High-Enthalpy Resources

China has over 200 high-enthalpy geothermal fields which may be suitable for power generation with reservoir temperatures higher than 150ºC (Zhijie, 1997). High-enthalpy resources are located in the East Taiwan Geothermal Zone which lies along the southern coast, and the Yunnan-Xizang (Tibet) Geothermal Zone located in the southwest plateau which includes the southern part of Xizang (Tibet) and the western parts of Yunnan and Sichuan Provinces.

Geothermal power generation in China began in 1970 with the commission of a 300 kWe plant at Fengshun. Several other small experimental power plants (less than 1 MWe) were built in the 1970s using artesian low-enthalpy water (< 90ºC) but only Dengwu is still operational, albeit intermittently. Currently, China has approximately 28 MWe of installed capacity. The single largest geothermal power plant currently operating is the 25.18 MWe complex at Yangbajian.

In 1999, ORMAT Holding Company signed a joint venture contract with the Yunnan Province Geothermal Development Co., Ltd. for exclusive electric power development of geothermal resources in Tengchong County, beginning with a 12 MWe plant at Rehai.

China's principal geothermal fields for power generation include Yangbajian, Naqu, Yangyi, and Langjui in Xizang Province (Tibet); Rehai, Lanpu, Ruidian, and Ruili in Yunnan Province; and Litang in Sichuan Province.

Estimated Power Generation Potential (MWe)

Estimates of China's geothermal electric power generation potential vary widely, from 200 MWe to over 10,000 MWe.

Hochstein and Yang, (1995) suggest a total potential of 200 MWe (excluding West Yunnan resources), Shen et al., (1995) suggest 400-1,100 MWe, Chen et al., (1994; cited in Wang et al., 1995) suggest 1,700 MWe (1,000 MWe in Tibet, 570 MWe in West Yunnan, 170 MWe in West Sichuan), and Ren et al., (1995) estimate over 6,000 MWe with a 30-year life (Allis et al., 1996).

Zhijie estimates that the potential power generation capacity on the Chinese mainland is 10,326 MWe for 30 years — 6,126 MWe in Tibet; 2,795 MWe in western Yunnan Province; and 1,045 MWe in western Sichuan Province (Zhijie, 1997).

Taking into account the 46 geothermal sites listed in this report with temperatures of over 150ºC, the estimated power generation potential is 1439.73 MWe at a minimum.

The GOC's goal is to have 30 MWe of installed power generation capacity from geothermal resources by 2000, 40-50 MWe by 2005, and 75-100 MWe by 2010 (Zhai, 2000).

If China is to achieve geothermal development approaching this magnitude within the next 10-20 years, there needs to be a reassessment of all major hot spring occurrences, incorporating both economic criteria as well as realistic estimates of resource potential. Much of the resource data has already been collated by the provincial and state Geological and Mineral organizations, so a large part of this study would be office based, using in-house expertise. "Reservoir" temperature estimates need to be based on the TKMg geothermometer rather than the TNaK geothermometer (Giggenbach, 1988), and caution is needed when using the area of thermal manifestations as an indicator of reservoir area. The mass flow of hot water and apparent reservoir temperature will yield a heat output which is probably the best indicator of reservoir size (Allis et al., 1996).

The following is data on those sites which have temperatures exceeding 150ºC, as well as the sites that have a power plant on location (several of which are no longer operational).

Project / Site	Province
Dengwu	Guangdong
Fengshun	Guangdong
Renzhou	Guangxi
Xiangzhou	Guangxi
Huailai	Hebei
Hui-Chang Spa	Hunan
Huitang	Hunan
Wentang	Jiangxi
Yichun	Jiangxi
Xiongyue	Liaoning
Zhaoyuan	Shandong
Chaluo	Sichuan
Litang	Sichuan
Panzhihua Boiling Springs	Sichuan
Yili	Xinjiang
Langjiu (Shiquanhe)	Xizang (Tibet)
Naqu	Xizang (Tibet)
Yangbajian	Xizang (Tibet)
Yangyi	Xizang (Tibet)
Yulingong	Xizang (Tibet)
Balazhang	Yunnan
Bangbie	Yunnan
Bongbeng	Yunnan
Caojian	Yunnan
Dakongbeng	Yunnan
Daping	Yunnan
Eryuan	Yunnan
Heishehe	Yunnan
Humeng	Yunnan
Lanniba	Yunnan
Lanpu Hot Pool	Yunnan
Lincang Hot Pool	Yunnan
Longmadong	Yunnan
Longwozhai	Yunnan
Malutianba	Yunnan
Mangwoshan	Yunnan
Manzhao	Yunnan
Maolan	Yunnan
Maomaolei	Yunnan
Mengman	Yunnan
Mengping	Yunnan
Niujie-Sanying	Yunnan
Quanqiaohe	Yunnan
Rehai (Hot Sea)	Yunnan
Reli	Yunnan

Reshuitang	Yunnan
Ruidian	Yunnan
Ruili	Yunnan
Wana	Yunnan
Xiabiaoyuan Xiaotang	Yunnan
Xiamiandian	Yunnan
Xiaodingxi-Xiaojie	Yunnan
Xiaojie-Manbeng	Yunnan
Xingfu	Yunnan
Yongxin	Yunnan
Yunnancheng	Yunnan
Zhaizhipo	Yunnan
Jiangsi Yichune	Zhejiang

Database entries are listed alphabetically by project or site name.

Balazhang

LOCATION
Yunnan Province, West Yunnan, Longling County, 1280 masl

STATUS
Preliminary identification/report

TEMPERATURE (°C) 98-214

INSTALLED CAPACITY (MWe) 0

POTENTIAL (MWe) N/A

CHRONOLOGY
1970s - Reconnaissance conducted in the Qinghai-Xizang Plateau.

NOTES
Site of 1 small geyser (Liao et al., 1984). China

Surface temperature is 98ºC, subsurface temperature is 214ºC (Liao et al., 1986).

Bangbie

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C) 63-177

INSTALLED CAPACITY (MWe) 0

POTENTIAL (MWe) N/A

CHRONOLOGY

NOTES
Surface temperature is 63ºC, subsurface temperature is 177ºC (Liao et al., 1986).

Bongbeng

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C) 95-205

INSTALLED CAPACITY (MWe) 0

POTENTIAL (MWe) N/A

CHRONOLOGY

NOTES
Surface temperature is 95ºC, subsurface temperature is 205ºC (Liao et al., 1986).

Caojian

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C) 61-170

INSTALLED CAPACITY (MWe) 0

POTENTIAL (MWe) N/A

CHRONOLOGY

NOTES
Surface temperature is 61ºC, subsurface temperature is 170ºC (Liao et al., 1986).

Chaluo

LOCATION
Sichuan Province, Western Sichuan, Batang County, 3600 masl

STATUS
Preliminary identification/report

TEMPERATURE (°C) 88-220

INSTALLED CAPACITY (MWe) 0

POTENTIAL (MWe) 10

CHRONOLOGY
1970s - Reconnaissance conducted in the Qinghai-Xizang Plateau.

NOTES
In the area near Chaluo, there are small geothermal fields with temperatures up to 220ºC and an estimated potential of 10 MWe.

Surface manifestations include fumaroles, boiling springs, thermal springs, and 4 geysers; located at the junction of two sets of faults with N-S and NE trends (Liao et al., 1984).

Dakongbeng

LOCATION
Yunnan Province, in the southwestern part of the province, 14 km west of Yunxian Town, about 180 km southeast of the Tengchong geothermal region, 1280 masl

STATUS
Preliminary identification/report

TEMPERATURE (°C)	97-212
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	11

CHRONOLOGY
1981 to 1983 - Preliminary survey, including geochemical study, conducted.

NOTES
Surface temperature is 97ºC, subsurface temperature is 212ºC (Liao et al., 1986).

Power generation potential estimated to be 11 MWe (Zhang, et al., 1984).

The Dakongbeng hydrothermal area is located tectonically within the Sanjiang folded strata belt which was formed during the Indo-China stage, and altered by stronger tectonic activity during the Yenshan and Himalayan stages (Zhang et al., 1984).

Daping

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C)	94-180
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES
Surface temperature is 94ºC, subsurface temperature is 180ºC (Liao et al., 1986).

Dengwu	
LOCATION Guangdong Province, in Fengshun County	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	87-94
INSTALLED CAPACITY (MWe)	0.866
POTENTIAL (MWe)	0.866
CHRONOLOGY 1970 - Dengwu U-2, single flash 386 kWe went online. 1973 to 1976 - General geothermal investigation carried out in Tibet. 1979 - Additional 180 kWe isobutane binary system began operating. 1982 - Dengwu U-3, single flash 300 kWe went online.	
NOTES Temperature is 87-94ºC; 13 MWt identified (Yang et al., 1985). During the 1970s, five binary plants, all less than 1 MWe, were installed around eastern China as pilot projects. These plants typically used water at 90ºC which flowed by artesian pressure from deep wells. As aquifer pressures decreased so too did flow rates; eventually pumping was needed to maintain flows making the plants uneconomic. The only ones still operating, albeit intermittently, are at Dengwu (Alls et al., 1996).	

Eryuan	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	69-204
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 68.8ºC, subsurface temperature is 204ºC (Liao et al., 1986).	

Fengshun
LOCATION

Guangdong Province, in the northeast part of the province, about 70 km from Shantou City
STATUS Power plant(s) on site

TEMPERATURE (°C)	95
INSTALLED CAPACITY (MWe)	0.5
POTENTIAL (MWe)	0.5

CHRONOLOGY

1970 - First geothermal power plant in China went online; flash plant; installed capacity of 300 kWe.

1977 - Additional 200 kWe binary plant went online; used isobutane-butane as working fluid

Plants currently operate intermittently.

NOTES

Mass flow rate is 240 t/h without deep well pumps (Zhou, 1983).

Average cost of the four pilot plants (Fengshun, Huailai, Wentang, and Xiongyue) was $3,000-$4,000/kW, two to three times the cost of a same size thermal plant. The average cost of electricity was about 66 mills/kWh, roughly equal to the cost of a same capacity thermal plant (Zhou, 1983).

Heishehe

LOCATION

Yunnan Province, in West Yunnan 30 km south of Tengchong

STATUS

Well(s) or hole(s) drilled

TEMPERATURE (°C)	125-200
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	23.9

CHRONOLOGY

NOTES

Concession to the local government of Heishehe

Geothermometer temperature of 200ºC

Area of 2 km²; temperature of 145ºC encountered at depth of 1500 m; potential estimated at 23.9 MWe for 30 years (Vaupen, 1999).

Huailai

LOCATION

Hebei Province, in Hualiai County; 92 km northwest of Beijing

STATUS Power plant(s) on site	
TEMPERATURE (°C)	85-88
INSTALLED CAPACITY (MWe)	0.2
POTENTIAL (MWe)	0.2
CHRONOLOGY Prior to 1971 - 3 wells drilled to average depth of 79 m; encountered average temperature of 83ºC; total mass flow rate of 210 t/h. (Zhou, 1983). September 1971 - 200 kWe binary plant commissioned; used ethyl chloride as working fluid; used all used equipment. Power plant currently not used.	
NOTES Geothermal resource is also used for greenhouses and farming. Average cost of the four pilot plants (Fengshun, Huailai, Wentang, and Xiongyue) was $3,000-$4,000/kW, two to three times the cost of a same size thermal plant. The average cost of electricity was about 66 mills/kWh, roughly equal to the cost of a same capacity thermal plant (Zhou, 1983). Temperature is 88ºC; 61 MWt identified (Yang et al., 1985).	

Hui-Chang Spa

LOCATION Hunan Province, in Ningxiang County	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	91
INSTALLED CAPACITY (MWe)	0.3
POTENTIAL (MWe)	0.3
CHRONOLOGY 1975 - 300 kWe flash system installed.	
NOTES	

Huitang

LOCATION Hunan Province	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	88-102

INSTALLED CAPACITY (MWe)	0.03
POTENTIAL (MWe)	0.03
CHRONOLOGY 1971 - Binary 30 kWe plant went online (Ren et al., 1990). Geothermal plant works intermittently.	
NOTES Geothermal resource is also used for greenhouses and farming. Temperature is 88-102ºC; 134 MWt identified (Yang et al., 1985).	

Humeng	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	94-172
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 94ºC, subsurface temperature is 172ºC (Liao et al., 1986).	

Jiangsi Yichune	
LOCATION Zhejiang Province	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	67
INSTALLED CAPACITY (MWe)	0.05
POTENTIAL (MWe)	0.05
CHRONOLOGY 1971 - 50 kWe ethyl chloride system went online.	
NOTES	

Langjiu (Shiquanhe)	
LOCATION Xizang (Tibet) Province, in the far western part of the province, 30 km east of Shiquanhe, 4500 masl	
STATUS Power plant(s) on site	

TEMPERATURE (°C)	78-180
INSTALLED CAPACITY (MWe)	2
POTENTIAL (MWe)	3.2

CHRONOLOGY

1973 to 1976 - General geothermal investigation carried out in Tibet.

Late 1970s - Survey suggested a subsurface temperature of 180ºC which might support a 10 MWe plant (Ren et al., 1995).

1980 to 1982 - Chinese and French earth scientists carried out geological, geophysical, and geochemical studies in Tibet (Grimaud et al., 1985).

Early 1980s - 13 wells drilled in 1-km² area to around 100 m; encountered temperatures of 101-105ºC in an inferred reservoir area of 0.4 km² (Allis et al., 1996).

1987 - Two single flash-steam 1-MWe plants installed; operating intermittently due to unsteady production from wells (Fangzhi, 1995).

NOTES

Only one plant is currently operational. Downward leakage of cold waters has damaged part of the reservoir and the maximum capacity of the field may now be only 3.2 MWe, down from the 10 MWe originally thought (IGA).

Concession to the Industry Bureau of Ali, Tibet

Lanniba

LOCATION

Yunnan Province, West Yunnan

STATUS

Preliminary identification/report

TEMPERATURE (°C)	93-157
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES

Surface temperature is 93ºC, subsurface temperature is 157ºC (Liao et al., 1986).

Lanpu Hot Pool

LOCATION

Yunnan Province, 10 km south of Rehai, in Tengchong County

STATUS Preliminary identification/report	
TEMPERATURE (°C)	96-220
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Lanpu is usually considered to be part of the Rehai geothermal field; its area is about 4.5 km². Discharge temperature is 96ºC (Zhang et al., 1987). Spring vents have shifted frequently. Prior to these migrations, hydrothermal explosions have occurred (Tong et al., 1986).	

Lincang Hot Pool

LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	64-177
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 64ºC, subsurface temperature is 177ºC (Liao et al., 1986).	

Litang

LOCATION Sichuan Province, near Litang township, in the western part of the province	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	190-220
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	10
CHRONOLOGY	
NOTES Several small fields; reservoir temperatures are in the 190-220ºC range. Due to the limited reservoir area, electric generation potential is probably less than 10 MWe.	

Longmadong

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C)	84-195
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES
Surface temperature is 84ºC, subsurface temperature is 195ºC (Liao et al., 1986).

Longwozhai

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C)	96-173
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES
Surface temperature is 96.5ºC, subsurface temperature is 173ºC (Liao et al., 1986).

Malutianba

LOCATION
Yunnan Province, West Yunnan

STATUS
Preliminary identification/report

TEMPERATURE (°C)	96-178
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES
Surface temperature is 96ºC, subsurface temperature is 178ºC (Liao et al., 1986).

Mangwoshan

LOCATION

Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	89-189
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 89ºC, subsurface temperature is 189ºC (Liao et al., 1986).	

Manzhao

LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	97-202
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 97ºC, subsurface temperature is 202ºC (Liao et al., 1986).	

Maolan

LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	68-152
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 68ºC, subsurface temperature is 152ºC (Liao et al., 1986).	

Maomaolei

LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	

TEMPERATURE (°C)	70-196
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 70ºC, subsurface temperature is 196ºC (Liao et al., 1986).	

Mengman	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	99-234
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 99ºC, subsurface temperature is 234ºC (Liao et al., 1986).	

Mengping	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	102-180
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 102ºC, subsurface temperature is 180ºC (Liao et al., 1986).	

Naqu
LOCATION Xizang (Tibet) Province, 2 km from Naqu Town (the largest nearby town with 1200 permanent residents, average annual temperature -1ºC) in Naqu County; 300 km north of Lhasa City; in northern Tibet; at 4526 masl
STATUS Power plant(s) on site

TEMPERATURE (°C)	62-170
INSTALLED CAPACITY (MWe)	1.3
POTENTIAL (MWe)	5.73

CHRONOLOGY
1973 to 1976 - General geothermal investigation carried out in Tibet.

1980 to 1982 - Chinese and French earth scientists carried out geological, geophysical, and geochemical studies in Tibet (Grimaud et al., 1985).

Mid to late 1980s - Geothermal assessments conducted and 20 exploratory wells drilled (most are now collapsed or corroded); located a 0.6 km² shallow reservoir with temperatures up to 170ºC. Work was done by the Geothermal Geological Team composed of Aquater S.p.A., the Instituto Internazionale per le Ricerche Geotermiche (Pisa, Italy), GENZL, and the Geothermal Development Corporation of Tibet Autonomous Region.

1993 - $5 million-grant from the United Nations Development Programme (UNDP) supported the installation of a 1.3 MWe air cooled binary Ormat plant. Plant operates off of 2 production wells with down hole pumps (70 ltr/s at 110ºC). A third production well provides hot water for district heating in the town.

The cable of one pump failed after 15 days of operation; the seal of the second after 7 months. The wells were operated without pumps and experienced severe scaling.

1995 - Plant ceased all operation. Due to remoteness of location, pumps were not replaced until 1998.

1998 - Pumps replaced; plant restored to full operating capacity by the Naqu Power Bureau.

NOTES
Naqu is the only completely stand-alone off-grid geothermal power plant in operation.

The operation is currently being changed so that pumps will no longer be necessary; anti-scalant injection will be used to prevent carbonate precipitations (Lichti et al., 1995).

A geothermal greenhouse at an elevation of 4500 m has been completed.

Niujie-Sanying

LOCATION
Yunnan Province, in the western part of the province, 87 km north of the city of Dali and 120 km east of the China-Burma border, 2050 masl. Dali is known as the

“Oriental Switzerland” because of its beauty, particularly its climate, flowers, and snow (Ping, 1999).

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	82-193
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY
1996 to 1998 - The Dali municipal government funded the geothermal project. Exploration activities included geological, geophysical, geochemical, and hydrological surveys; the drilling and logging of wells; and an assessment of the geothermal resource. Electrical sounding and spontaneous potential surveys were carried out to delineate the geothermal anomaly.

During the 1996-98 project, nine shallow temperature gradient and two exploration wells were drilled. The 260 m-deep well ZK203 penetrated the reservoir between 150 and 230 m depth in Devonian limestone, some breciated; borehole temperatures as high as 140.8ºC were recorded.

Forty-four (44) water samples were collected and analyzed. The hot waters are mainly of $Na\text{-}HCO_3$ type, while the cold waters are of $Ca\text{-}Mg\text{-}HCO_3$ type.

The total flow rate of ZK203 was 7.4 kg/s at a wellhead pressure of 1.5 bar g. Rapid calcite scaling was observed during the 15-day production test due to high CO_2/steam ratio in the geothermal fluid (Ping, 1999).

NOTES
Originally, the field was explored for electrical generation, particularly during the dry winter and spring seasons when hydroelectric power is scarce. However, exploration and well testing studies showed that the temperature of the fluids was too low to produce electricity economically. Now the authorities plan to develop the field for industrial applications, balneology, and tourism (Ping, 1999).

Local people currently use the hot spring waters, whose temperatures range from 42ºC to 86ºC, for bathing, washing clothes, and cooking.

Surface temperature is 81.5ºC, subsurface temperature is 193ºC (Liao et al., 1986).

The Niujie geothermal system is in a narrow North-South trending graben filled with Quaternary clay and alluvium. Hot water flows along N-S striking faults (Ping, 1999).

Panzhihua Boiling Springs

LOCATION Sichuan Province	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	97-187
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	49.4-78
CHRONOLOGY Prior to the 1960s - Hydrothermal explosions frequently occurred (Tong et al., 1986).	
NOTES Discharge temperature is 96.8ºC; most likely geothermometer temperature is 187ºC (Zhang et al., 1987). Area of 2 km²; temperature of 145ºC at 1500 m; potential electricity estimated at 49.4 MWe for 30 years (Vaupen, 1999). Estimated potential is 78 MWe; 39 MWt (Yang et al., 1985).	

Quanqiaohe

LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	96-190
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 96ºC, subsurface temperature is 190ºC (Liao et al., 1986).	

Rehai (Hot Sea)

LOCATION Yunnan Province, 11 km southwest of Tengchong township in western Yunnan Province, near the border with Burma; at the southern end of the Himalayan Geothermal Belt; situated at 24º51'-24º58'N and 98º23'-98º-28' E; 1098-1912 masl	
STATUS Concession	

TEMPERATURE (°C)	97-235
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	233.5

CHRONOLOGY

1976 to 1992 - 13 shallow test holes, ranging in depth from 100 to 400 m, were drilled; based on measurements and other information, it is possible to say that Rehai is a hot water system with a magmatic heat source of about 400-600ºC; reservoir temperature estimated to be 230-275ºC (Taylor and Li, 1996).

1995 - Supplementary survey; arranged for deep drilling to clarify resource; five bores planned.

1999 - ORMAT Holding Company signed a joint venture contract with the Yunnan Province Geothermal Development Co., Ltd. for exclusive electric power development of geothermal resources in Tengchong County. ORMAT will be a 85% partner in the venture which will sign a power purchase agreement with Yunnan Province Electric Power Corp.

The project's first phase will be construction of a 12 MWe power plant. Currently, the local power grid can only take 10-20 MWe of added capacity (Allis et al., 1996). Total power potential of the steam field is estimated at over 200 MWe, which ORMAT believes can be developed over a five- to seven-year period after operations begin. Initial investment will be approximately $30 million.

The Yunnan Province pricing policy for Tengchong County isolated grid is to allow the Tengchong Power Bureau to establish end-use prices. Prices for isolated grids are calculated by considering capital and operating costs, interest for servicing debt, and a 15% rate of return for equity investment. Power prices for isolated grids reach as high as 10¢/kWh (Allis et al., 1996).

The power generation price ranges from 6.7¢/kWh to 7.8¢/kWh depending on VAT and import duties (Allis et al., 1998).

NOTES

The Rehai geothermal field is considered to have the greatest power generation potential in China. It is the largest geothermal system in mainland Asia outside of Kamchatka. The field's potential power generation potential is estimated to be 233.5 MWe for 30 years (Vaupen, 1999).

Ten shallow wells have been drilled around the Rehai field, apparently as part of gold exploration. The holes were not located close to the thermal activity, but measured temperatures of up to 142ºC at 380 m depth (Allis et al., 1996).

Geochemical surveys indicate that there are two reservoirs at Rehai, one in the 180-210ºC range; the other higher than 250ºC (Zhao, 1995).

Thermal activity at Rehai includes boiling springs; hot water pools; fumaroles; steaming ground; fiorite, adarce, salt tufa, and minerogenetic phenomena of hydrothermal gold and silver; sinter and travertine formations; thermally altered ground; and sulfur deposits. The area has attracted tourists as well as patients wishing to recuperate in the thermal waters (Allis, et al., 1998). The geothermal resource is currently used for a health spa (IGA).

A complicating factor regarding the development of the Rehai field is the special value the springs have as a tourist attraction; their intensity is unique in China (Allis et al., 1996).

The Rehai geothermal field covers an area of about 100 km² which includes two geothermal areas 6 km apart and separated by a mountain -- Liuhaungtang (Huangguaqing-Songmuqing) to the east and Reshuitang to the west. Liuhaungtang has an estimated reservoir temperature of 238ºC and a shallow reservoir temperature of 164ºC (Vaupen, 1999).

The main thermal features occur along a 2 km stretch of the Zaotanghe River, and along a 2.5 km lineament at right angles to the river between Liuhuangtang and Huangguaqing. The immediate source of these waters is likely to be to the north beneath the flanks of Mt. Bangeshan (Allis, et al., 1998).

The natural heat flow has been estimated at more than 100 MWe. The high temperature spring waters indicate a relatively dilute sodium chloride-bicarbonate water (< 500 mg/kg Cl), with increasing sulphate concentrations found at higher elevations where steam-heating has occurred. A total chloride flux from the Rehai hot springs of 44 g/s has been measured, which also implies a heat flow of almost 100 MWth assuming the parent fluid has an enthalpy of 1000 kJ/kg and a chloride concentration of 500 mg/kg (uncertainties of over 25% in these assumptions (Allis et al., 1996).

Anomalously shallow seismicity beneath the region (< 7 km) and a low resistivity anomaly in the upper crust are consistent with very high temperatures from a cooling intrusion (i.e. > 350ºC) (Allis et al., 1996).

The water chemistry is mainly HCO_3-Cl-Na type and Cl-HCO_3-Na type.

A conservative estimate of the natural heat output from both direct measurements and indirect chloride flux methods is 150 ± 50 MWt. Geochemical equillibria derived from thermal waters suggest a reservoir temperature of 250-270ºC, and gas chemistry equillibria are consistent with subsurface temperatures of 200-300ºC. The subsurface area of the field and the potential reservoir location are poorly defined. If the Reshuitang (hot) and Bapai (tepid) springs are also outflows from the same deep geothermal resource, then the area of the field could be as much as 50 km², and the natural heat output could be close to 200 MWt (Allis, et al., 1998).

Reli

LOCATION
Yunnan Province, on the bank of the Lijiang River, Reli City is an important commercial and trade port with three international borders

STATUS
Preliminary identification/report

TEMPERATURE (°C)	215-227
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	19.8

CHRONOLOGY

NOTES
Reli geothermal field has an area of 11.8 km², reservoir temperatures of 215-227ºC, and an estimated capacity of 19.8 MWe (Ren et al., 1995).

Peacock Hot Spring is famous for its high temperatures (96-102ºC) and beautiful scenery.

Renzhou

LOCATION
Guangxi Province

STATUS
Power plant(s) on site

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWe)	0.1
POTENTIAL (MWe)	0/1

CHRONOLOGY

NOTES
Power plant no longer operating.

Reshuitang

LOCATION
Yunnan Province, 8 km southwest of the Rehai field, 1119 masl

STATUS
Preliminary identification/report

TEMPERATURE (°C)	145-221
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	96

CHRONOLOGY

NOTES
A hot spring with a temperature of 98.7ºC is found halfway up the mountain (Ren et al., 1995).

Shallow reservoir temperature is 145ºC (Vaupen, 1999).
Field has estimated temperatures of 161-221ºC and a possible capacity of 96 MWe.

Reshuitang has two boiling springs with a total flow of 13 kg/s, implying a natural heat flow of close to 5 MWt. This spring is situated in the Dayingjian River Valley at approximately 1100 masl (Allis, et al., 1998).

Reshuitang hot springs may be manifestations of the same deep heat source as Rehai to the north (Allis et al., 1996).

Ruidian

LOCATION
Yunnan Province, 60 km north of Tengchong township in western Yunnan, 1700 masl

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	86-200
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	47.2-56.36

CHRONOLOGY

NOTES
The Ruidian geothermal field, with an area of about 3 km², contains 33 warm and hot springs with an average temperature of 50-75ºC, and a maximum temperature of 97ºC. Discharge temperature is 86.5ºC; composed of 6 groups of hot springs (Zhang et al., 1987).

Thermal reservoir geothermometer temperature is 200ºC; power generation potential is estimated at 56.36 MWe for 30 years.

Area of 3.2 km²; temperature of 160ºC at 1500 m; potential electricity estimated at 47.2 MWe for 30 years (Vaupen, 1999).

Direct use potential estimated at 39 MWt (Yang et al., 1985).

Ruili	
LOCATION Yunnan Province, on the bank of the Lijiang Ruver near Ruili City, an important commercial and trading port on the Burmese border; about 100 km south of Tengchong; in western Yunnan; 760-774 masl	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	215-230
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	3-5
CHRONOLOGY	
NOTES Two wells drilled to 1200-1500 m depth encountered maximum temperature of 100ºC; reservoir temperatures are in the range of 215-230ºC; field is 12 km² in size; initial plant of 3-5 MWe planned. Israeli and Italian companies are doing demonstration projects at Ruili (Gebert, 1997).	

Wana	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	88-154
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 87.5ºC, subsurface temperature is 154ºC (Liao et al., 1986).	

Wentang	
LOCATION Jiangxi Province, in the western part of the province; 21 km from Yichun City	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	66-70
INSTALLED CAPACITY (MWe)	0.1

POTENTIAL (MWe)	0.1
CHRONOLOGY September 1971 - First 50 kWe binary plant went online; used ethyl chloride as working fluid.	
NOTES Two 50 kWe plants were put into operation. Waste fluid used for direct use. One 8"” well was drilled to a depth of 69 m; encountered temperature of 66ºC and a mass flow rate of 80-100 t/h. Well is artesian; no pump is required (Zhou, 1983). Average cost of the four pilot plants (Fengshun, Huailai, Wentang, and Xiongyue) was $3,000-$4,000/kW, two to three times the cost of a same size thermal plant. The average cost of electricity was about 66 mills/kWh, roughly equal to the cost of a same capacity thermal plant (Zhou, 1983).	

Xiabiaoyuan Xiaotang Spring

LOCATION Yunnan Province, Tengchong	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	25-156
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Discharge temperature is 25ºC; most likely geothermometer temperature is 156ºC (Zhang et al., 1987).	

Xiamiandian

LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	71-170
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 71.4ºC, subsurface temperature is 170ºC (Liao et al., 1986).	

Xiangzhou	
LOCATION Guangxi Autonomous Region	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWe)	N/A
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES	

Xiaodingxi-Xiaojie	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	94-207
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 94ºC, subsurface temperature is 207ºC (Liao et al., 1986).	

Xiaojie-Manbeng	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	101-175
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 100.7ºC, subsurface temperature is 175ºC (Liao et al., 1986).	

Xingfu	
LOCATION Yunnan Province, West Yunnan	
STATUS	

Preliminary identification/report	
TEMPERATURE (°C)	95-221
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 95ºC, subsurface temperature is 221ºC (Liao et al., 1986).	

Xiongyue

LOCATION Liaoning Province, about 64 km from Yingkou City	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	72-85
INSTALLED CAPACITY (MWe)	0.2
POTENTIAL (MWe)	0.2
CHRONOLOGY 1971 - First 100 kWe dual freon binary system went online. May 1978 - Second 100 kWe binary plant went online using F-11/n-butane as working fluid.	
NOTES Two 100 kWe power plants stopped operations. Geothermal resource is also used for greenhouses and farming. Estimated 7 MWt identified (Yang et al., 1985). Two wells were drilled; total flow rate of 120 t/h; encountered temperature of 80ºC (Zhou, 1983). Average cost of the four pilot plants (Fengshun, Huailai, Wentang, and Xiongyue) was $3,000-$4,000/kW, two to three times the cost of a same size thermal plant. The average cost of electricity was about 66 mills/kWh, roughly equal to the cost of a same capacity thermal plant (Zhou, 1983).	

Yangbajian

LOCATION Xizang (Tibet) Province, 94 km northwest of Lhasa City, the capital of the Tibet Autonomous Region, in a basin bordered by the Nyaingentanglha Mountains to the north and by the Tang Mountains and Zangboqu River to the south; at an elevation of 4290-4450 masl. The China-Nepal highway divides the field into two

parts, the northern and southern; at the junction of the China-Nepal Highway and the Qinhai-Xizang Highway	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	125-330
INSTALLED CAPACITY (MWe)	25.18
POTENTIAL (MWe)	900

CHRONOLOGY

1973 to 1976 - General geothermal investigation carried out in Tibet.

1975 - First shallow geothermal well drilled.

1976 - Tibetan Geological Team established; more detailed exploration began; found a shallow reservoir between 150 and 300 m; encountered temperatures of 150-165ºC which decreased towards the southeast; extended over an area of 4-5 km² (Ping and Ji, 1999).

1977 - Electricity generation began; Yangbajian No. 1 experimental stage of 1 MWe went online at a reported cost of US$40 million (IGA).

1981 - First 3 MWe went online.

1982 - Second 3 MWe went online.

1983 - Under UNDP contract, ENEL-AQUATER (ENI) began geothermal research.

1985 - Third 3 MWe went online; ENEL-AQUATER concluded reservoir and production engineering study.

1986 - Additional 3.18 MWe went online.

1988 - Borehole with a measured temperature of 202ºC at 970 m was drilled in the north hydrothermal alteration area.

1989 - Additional 6 MWe (2 x 3) went online.

1991 - Additional 6 MWe (2 x 3) went online; total installed capacity increased to 25.18 MWe. (While the power plant has an installed capacity of 25.18 MWe, it generally produces only 16 MWe due to insufficient flow rates [Ping, et al., 1997].)

1993 to 1994 - In order to increase the installed capacity and address the decline in pressure, exploration of the deep reservoir was begun in the northern part of the field. The first deep well, ZK4002, to 2006.8 m, was successfully drilled. The recorded temperature in May 1994 was 329.8ºC at 1850 m depth (the borehole has since collapsed at that depth [Ping, et al., 1997]), with a wellhead temperature of 200ºC which later stabilized at 125ºC with a pressure of 0.14 MPa, down from 1.5 MPa. Due to its low production characteristics, the well will not be connected to a power plant.

1996 - Successfully completed ZK4001, 370 m southeast of ZK4002; drilled to 1450 m; average temperature is 248ºC in the feeding zones (Ping, et al., 1997). The shallow, 170ºC feed zone is in fractured granites between 240-450 m depth. Below this zone, the well penetrates altered granite at 450-790 m, and dense granite at 690-950 m. The deepest part of the well is fractured granite at 950-1366 m, and granitic mylonite at 1336-1450 m (Ping and Ji, 1999). Wellhead conditions were 200ºC and 1.5 MPa when flowing at a rate of 84 kg/s (steam and liquid). NaCl is the main component of the deep fluid. The estimated reservoir temperature is 248.9ºC (based on Fournier's 1977 quartz geothermometer), and 275ºC (based on Arnorsson et al.'s 1983 Na/K geothermometer) (Ping and Li, 1999).

Logging and hydraulic tests verify that there are high temperature fluids in the northern part of the field which could be used to produce more electricity. Exploitation of the deep resources would accelerate the shallow resources depletion. In order to extend the life of the field, it is necessary to set up an injection project as soon as possible (Ping, et al., 1997).

Reinjection could be carried out in one of two ways. The first is to put the reinjection wells in the northern part of the field to mix with the recharge water in the vertical convection before the water enters the reservoir at 140ºC. The second is to put the reinjection wells in the southern part of the field close to the power plant and to use the 80ºC cold waste water from the plant (Hu, 1995).

1998 - Drilling of four injection wells began; disposal of the cool discharge waters into the local surface drainage is now regarded as an acceptable form of pollution (Allis et al., 1996).

1999 - Japan International Cooperation Agency (JICA) decided to contribute 591 million yen (about US$4.5 million) to the development of Yangbajian, including the further assessment of the deep reservoir and ZK4001.

Local government proposed a new geothermal exploration program for northern Yangbajian, hoping to receive financial support from the central government in Beijing (Ping and Ji, 1999).

2000 to 2002 - JICA three-year project will fund two directional drill holes, a high-frequency magnetoteluric survey, the installation of six microseismic monitoring stations, a CO2 soil gas survey, fluid geochemistry studies, and a new assessment of the Yangbajian resource (Ping and Ji, 1999).

Yangbajian generates 41% of the power needed by Lhasa City in summer and more than 60% of the city's winter needs, when hydropower is ineffective.

NOTES
Yangbajian is home to the largest geothermal power plant in China. Yangbajian geothermal field covers a total area of about 15 km² although the accessible part of the upper reservoir from which hot fluids can be produced covers only about 4 km². The field is a liquid-dominated reservoir with a two-phase zone on the top (Hu, 1995).

More than 80 wells have been drilled at Yangbajian, most of them shallow. As of 1999, less than 15 are productive; the rest are either damaged or are exploration wells.

Calcite scaling in the field is very serious. The production wells require daily reaming by use of hammer-striking (Ping, et al., 1997). During the last years, pressure in the production wells has dropped sharply; there is insufficient steam available to run the turbines at full load. Injection of waste geothermal fluids will begin soon in order to extend the commercial life of the shallow reservoir.

The waste waters from Yangbajian are used to heat 50,000 m² of greenhouses (Allis et al., 1996).

Yangbajian geothermal field is one of ten hydrothermal anomalies along the Nyainqen-Tanglha Fault (Xu and Wu, 1990).

Yangyi

LOCATION
Xizang (Tibet) Province, 60 km from Lhasa City; 45 km southwest of Yangbajian; 4550 masl

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	150-207
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	30

CHRONOLOGY
1973 to 1976 - General geothermal investigation carried out in Tibet.

1980 to 1982 - Chinese and French earth scientists carried out geological, geophysical, and geochemical studies in Tibet (Grimaud et al., 1985).

Early 1990s - Temperature, pressure, and flow rate stable during almost 900 hours of testing; 85 wells drilled; 15 wells ranging up to 1100 m depth have located a 200-207ºC zone about 1.5 km² in area.

In well 208, a temperature of 207.16ºC was measured at a depth of 312 m. The content of CO_2 is relatively low; $CaCO_3$ scaling in the well might be slight (Ren et al., 1995).

1996 - A 10 MWe development proposal was submitted to the Ministry of Electric Power (Allis et al., 1996).

NOTES
The Yangyi geothermal field is in the same basin as Yangbajian (Ping, et al., 1997). It has an area of 11 km².

The power potential of the shallow reservoir is estimated to be 30 MWe, but comparisons with the production experience at Yangbajian, where the reservoir volume is perhaps 3 times greater, suggests that this estimate is optimistic (Allis et al., 1996).

Yichun

LOCATION
Jiangxi Province

STATUS
Power plant(s) on site

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWe)	0.1
POTENTIAL (MWe)	0.1

CHRONOLOGY
1971 - Two 50 kWe binary plants went online.

NOTES

Yili

LOCATION
Xinjiang Province

STATUS
Preliminary identification/report

TEMPERATURE (°C)	160-180
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES

Yongxin

LOCATION
Yunnan Province, West Yunnan

STATUS Preliminary identification/report	
TEMPERATURE (°C)	97-158
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 97ºC, subsurface temperature is 158ºC (Liao et al., 1986).	

Yulingong	
LOCATION Xizang (Tibet) Province, in Kangding County; 10 km south of Kangding City; along the Kangding Fault	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	135-170
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY 1982 - Survey of hot springs conducted.	
NOTES Estimated minimum subsurface temperatures of the reservoir at 135ºC to about 170ºC. A conservative estimate shows that the potential reservoir could be 4 km long, 1 km wide (Liao and Zhang, 1983).	

Yunnancheng	
LOCATION Yunnan Province, West Yunnan	
STATUS Preliminary identification/report	
TEMPERATURE (°C)	99-166
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 99ºC, subsurface temperature is 166ºC (Liao et al., 1986).	

Zhaizhipo	
LOCATION Yunnan Province, West Yunnan	

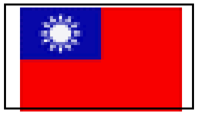
STATUS Preliminary identification/report	
TEMPERATURE (°C)	50-165
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Surface temperature is 50.3ºC, subsurface temperature is 165ºC (Liao et al., 1986).	

Zhaoyuan

LOCATION Shandong Province	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	90-120
INSTALLED CAPACITY (MWe)	0.2
POTENTIAL (MWe)	0.2
CHRONOLOGY	
NOTES Power plant no longer operating.	

Estimated 17 MWt possible (Yang et al., 1985).

Taiwan



Taiwan

Power Profile

Population (millions) - July 1999 estimated	22.11
Overall Electrification (% of population)	100%
GDP (billion US$) - 1998 estimated	$362.00
Real GDP Growth Rate - 1998 estimated	4.8%
Inflation Rate (CPI) - 1998	2.1%
Total Installed Capacity (MWe) - 1998	26
Electricity Consumption per Capita (kWh) - 1997	5,606.47
Energy Demand Growth Rate	10%
Prices (US¢/kWh)	
Residential - 1998	8.9
Industrial - 1997	6.9
Source: the U.S. International Energy Agency	

Taiwan's relationship with the Chinese mainland remains problematic; both the PRC and Taiwan assert that there is only "one China." Taiwan authorities seek recognition as one of what they claim are two "sovereign" political entities, each governing part of China, while the PRC regards itself as the sole legal government of all of China and Taiwan its 23rd province, Taipei.

Although the United States does not have diplomatic relations with Taiwan, the U.S.-Taiwan relationship is generally excellent. The American Institute in Taiwan, a private, non-profit institution, was established in 1979 to maintain the unofficial relations between the peoples of the United States and Taiwan. More than 40 other countries, including most major European and Asian nations, also maintain unofficial representation.

Power Summary

Taiwan has an installed capacity of approximately 26 MWe. Imported oil is the dominant fuel in Taiwan's energy mix, accounting for more than half of total primary energy consumption. Coal also plays an important role (over 30% of total energy consumption), followed by nuclear power (over 10%), natural gas (over 5%), and hydroelectric power (around 3%).

At the end of 1998, Taiwan Power Company (Taipower), the state electric power utility, operated 69 power plants (39 hydropower, 27 thermal, 3 nuclear) with a total capacity of 26,680 MWe. In addition, co-generators had 2,500 MWe of capacity which generated around 10% of the country's total electric power. (Since 1988, Taiwan has had a policy of encouraging large industrial facilities to build co-generation capacity.)

Taiwan's energy demand is growing fast and expected to double by 2010, increasing from the 137.8 billion kWh used in 1997 to 232.5 billion kWh by 2010. To avoid a repeat of the power shortages of the summer of 1999, under an ambitious construction schedule, Taipower's installed capacity (including IPPs) should reach 44.223 GWe by the end of 2007.

Taiwan's energy supply depends heavily on imported fuel, which reached 96% of total energy needs in 1998. To decrease its energy imports and accommodate the Kyoto Protocol on global CO_2 emissions, Taiwan's renewable energy development program is a top priority within Taiwan's energy policy. Its goal is to increase use of renewable energy to between 1% to 3% of its total energy supply by 2020.

Government / Legislation

Taiwan Power Company (Taipower)

Currently, state-run Taipower monopolizes the generation, transmission, and distribution of electricity. Taiwan has been reducing the public sector's role in the economy in an effort to reduce the central authorities' budget deficit. Taipower's monopoly status has been waning since a 1994 measure allowed IPPs to provide up to 20% of Taiwan's electricity.

The planned privatization is largely the result of rapidly rising power demand in Taiwan, and Taipower's inability to build sufficient capacity to keep pace with demand, which led to a power crisis during the summer peak-demand months of 1999. The expected date for Taipower's privatization is July 2001. Taipower will retain exclusive control over nuclear and hydropower plants. The government will continue to own these plants after Taipower is privatized.

Taiwan authorities fear the island will be crippled by power shortages if Taipower continues to be the sole power provider. Taipower's power generation reserve margin is as low as 5.6%.

Eight IPPs have been authorized to build power plants and the first one went into operation in May 1999. Another three will start supplying power in 2000 and

2001. As a result, the reserve capacity of the power grid is expected to increase from 5.6% in 1996 to 9% in early 1999 and 15-20% in 2000.

IPPs are required to sign power purchase agreements with Taipower, which will distribute the power to market. However, new regulations issued by the government in July 1998 will allow foreign investors to play a greater role in Taiwan's electric transmission and distribution sector. The new rules raised the level permitted of foreign investment in these sectors to 50%, from 30% previously.

A private firm can apply to build and operate a power plant if the following six conditions are met:

1. Its environmental impact assessment (EIA) is approved by the Taiwan authorities,
2. The local government consents to the construction of the power plant,
3. The power plant has a secure source of fuel,
4. Taipower agrees to transmit electricity generated by the plant to its power transformation stations,
5. The landowner consents to the use of the land and the government approves the re-zoning of the land, and
6. Banks offer adequate project financing.

In addition, Taiwan authorities continue to reduce tariffs and non-tariff barriers as part of Taiwan's anticipated accession to the World Trade Organization. Restrictions on financial institutions are gradually being lifted; several public firms have been privatized; and private sector competition is being introduced in telecommunications, power generation, and oil refining and distribution.

Ministry of Economic Affairs (MOEA)

In the wake of Taiwan's devastating earthquake on September 21, 1999, Taiwan's Ministry of Economic Affairs (MOEA) announced plans to further ease the rules under which private companies may set up power plants at Taiwan's industrial parks. The new rules will help ensure that industrial parks do not experience further disruption of electricity supplied by Taipower.

MOEA has proposed to Taiwan's Cabinet, the Executive Yuan (EY), a further liberalization of the electricity industry. The MOEA also plans to set a ceiling price for the electricity generated by general operators.

Under current regulations, the MOEA permits only companies located in an industrial park to build co-generation plants in that park. Under the new Power Utility Law, however, companies at the parks may partner with companies outside the park to invest in power generation facilities. Those power plants may also sell surplus electricity to Taipower and other customers. At the same time, however, the MOEA will also eliminate certain investment tax credit incentives and preferential loans for investments in co-generation plants.

Energy Commission (EC)

In late November, 1999, officials from Taiwan's Energy Commission (EC) announced that it has agreed with the EY on a plan for liberalization of Taiwan's energy market. Passage is expected by Taiwan's Legislature in mid-2000 (Heimer, 1999). The major features of the plan are:

1. Taipower will remain an integrated utility, but other companies may also provide integrated services and compete with Taipower throughout the generation, transmission and distribution sectors.

2. The authorities will not set up a pool system. However, IPPs and co-generation plants may themselves contract to buy and sell electricity among themselves.

3. New IPPs will not be required to enter into a Power Purchase Agreement (PPA) with Taipower. Although new IPPs will still be required to first obtain a license from the EC, the EC does not expect license qualifications for new IPPs to differ much, if at all, from the qualifications currently required for IPPs.

4. Taipower and an existing IPP may terminate the PPA between them upon mutual agreement.

5. New capacity at existing IPPs will not be subject to a PPA. (Hereinafter "New IPPs" refers to (a) the new IPPs referred to in point (3), (b) the IPPs which have terminated their PPA with Taipower referred to in point (4) and (c) the new capacity referred to in this point (5).)

6. IPPs (current and New) will be able to compete with Taipower for certain "contestable customers" by entering into bilateral agreements with the contestable customers. IPPs will not be able to compete for "captive customers." Generally speaking, contestable customers will be industrial users, and captive customers residential users.

7. New IPPs may directly supply end users through the construction of transmission lines.

8. Sales of electricity between an IPP and a contestable customer which do not take place over private distribution lines, as well as sales of electricity between an IPP and Taipower, will be through an independent system operator (ISO). The ISO will be a non-profit entity organized by the Taiwan authorities. It will charge the IPP a nominal fee to cover its costs and pass along a fee charged by the transmission sector (currently envisioned to include only Taipower and other integrated utilities but theoretically including transmission specialist companies) for transmission and distribution services. It is not clear whether the liberalization plan would eventually permit transmission over lines built pursuant to contracts between an IPP and an end user. The EC claims the ISO system they contemplate is similar to the system in place in California.

9. Electricity generators will be required to (a) generate a certain percentage of their electricity using hydro, nuclear, LNG or renewable resources or (b) otherwise support clean or renewable generation by making additional purchases from generators using those resources or paying into a government fund.

10. IPPs and Taipower will be required to provide backup power to each other.

11. Co-generation plants licensed for "self-use," often situated in industrial parks, will be able to sell up to 20% of their capacity to contestable customers. Co-generation plants may also be licensed, and treated, as regular IPPs, but the "self-use" license is easier to obtain.

12. All limitations on foreign investment in the energy sector will be removed.

13. The new plans do not require or anticipate Taipower privatization. However, the MOEA has recently announced that, post-privatization, Taipower will be required to maintain separate financial statements across its major businesses to prevent cross-subsidization from its business lines where it maintains an effective monopoly to those lines in which it competes.

The new plan appears to go far to liberalize the Taiwan energy sector and the potential opportunities for US business interest appear great. However, critical details still need to be clarified ((Heimer, 1999).

Renewable Energy Policy

Taiwan's renewable energy program is in its early development. Immediately after Taiwan's National Energy Convention in May 1998, the EC established a New and Clean Energy Research and Development Group. The group has started reviewing the policies towards, and R&D of, renewable energy in Taiwan, particularly focusing on solar energy, photovoltaic energy, wind energy, biomass energy, geothermal energy, hydraulic energy, and ocean thermal energy.

The Taiwan authorities have a strong desire to achieve the Kyoto Protocol emission standards and are promoting renewable energy. U.S. suppliers should market their products in Taiwan by contacting the EC, the Energy & Resources Laboratories of the Industrial Technology Research Institute, Taiwan Power Company, Taiwan's Environmental Protection Administration, and local engineering firms (Chen and Heimer, 1999).

Geothermal Law

Taiwan has no geothermal law.

Taiwan, Shaded Relief, 1992

University of Oregon, http://darkwing.uoregon.edu/~felsing/cstuff/cmaps.html

Geothermal Sites / Projects

The island of Taiwan is situated in an Cenozoic tectonically active belt of the Pacific Island Arc system in which recent volcanism and seismic activities are still common, as evidenced by the September 21, 1999 earthquake.

Taiwan began exploring its geothermal resources for power generation potential in the 1960s. There are currently 103 thermal springs identified on the island, 69 of which have recorded temperatures and flow rates; 18 springs have surface temperatures exceeding 80ºC (Zhijie, 1997).

Due to the unresolved corrosion problems in the Pleistocene Tatun volcanic region in the north of the country, exploration shifted to the Slate Terrain which is underlain chiefly by the Miocene Lushan Formation of Ho (Chang and Lee, 1980; Cherng, 1979).

The highest subsurface temperature found in the Slate Terrain region is 223ºC at a depth of 2,003 meters in the Qingshui area. The lowest downhole temperature is below 173ºC at a shallow depth (100-500 m) in the Tuchang and Lushan areas. From the chemical geothermometers and mixing models, the deep reservoir temperature is estimated to be in the 195-220ºC range, similar to the subsurface temperature at Qingshui (Cherng, 1979).

With the exclusion of the Pleistocene Tatun volcanic group on the northernmost tip of the country, Taiwan has an estimated geothermal power potential of 100-500 MWe (Lee, et al., 1981). Taiwan currently has a geothermal installed capacity of 4.5 MWe at Qingshui and 300 kWe at Tuchang.

Information on the following sites follows:

1. Chihpen
2. Chiniun
3. Lushan
4. Pingdong
5. Qingshui (Chingshui)
6. Sanshing
7. Tatun (Datong)
8. Tuchang

Chihpen	
LOCATION In southeastern Taiwan	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY	
NOTES Shallow drillings (< 500 m) done by the Mining Research and Service Organization (MRSO). Deeper drillings done by the Chinese Petroleum Corporation (CPC). Water chemistry characterized by high content of sodium bicarbonate (> 2000 ppm), saturated silica, and low concentration of chloride and sulfate (< 50 ppm). At depth, dissolved carbon dioxide is relatively increasing in the thermal fluid (Chang and Cheng, 1981).	

Chiniun

LOCATION	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY	
NOTES Shallow drillings (< 500 m) done by the Mining Research and Service Organization (MRSO). Deeper drillings done by the Chinese Petroleum Corporation (CPC).	

Lushan

LOCATION In central Taiwan south of the Tuchang field	
STATUS Direct use -- developed	
TEMPERATURE (°C)	59-173
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	30
CHRONOLOGY	
NOTES The Lushan geothermal resource is currently used for industrial processes. The mixing models of the hot springs yield an estimated temperature of 195-220ºC for the deep aquifer temperature of the field (Cherng, 1979). The potential of the field is estimated to be nearly 30 MWe (Chang and Lee, 1980). Many high temperature hot springs are found in this	

field; the average spring temperature is 65ºC (59-96ºC) (Cherng, 1979). The highest hot spring surface temperature recorded is 98ºC (Chang and Lee, 1980).

Shallow drillings (< 500 m) done by the Mining Research and Service Organization (MRSO). Deeper drillings done by the Chinese Petroleum Corporation (CPC).

Exploration well NL-2 drilled to 500 m; encountered maximum down hole temperature of 173ºC at 450 m and maximum static pressure of 50 kg/cm^2.

Water chemistry characterized by high content of sodium bicarbonate (> 2000 ppm), saturated silica, and low concentration of chloride and sulfate (< 50 ppm). At depth, dissolved carbon dioxide is relatively increasing in the thermal fluid (Chang and Cheng, 1981).

High gas content in steam may limit the exploitation of geothermal resources if the conventional power generation method is used. Scaling in the well head equipment and pipeline is also an engineering problem related to the high gas content in steam (Chang and Cheng, 1981).

Hot water in this metamorphic terrain has higher pH values of 7 to 9.8 due mainly to the high concentration of $NaHCO_3$ (Cherng, 1979).

The Lushan Formation is composed mainly of argillite and slate of Early Miocene or lower-Middle Miocene age exposed in the main part of the Central Range (Cherng, 1979).

Pingdong

LOCATION
In Gaoxing County

STATUS
Preliminary identification/report

TEMPERATURE (°C)	140
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A

CHRONOLOGY

NOTES
The Pingdong hot spring has a temperature of 140ºC (Huang, 1980).

Qingshui (Chingshui)

LOCATION
On the western flank of the Central Range in northeastern Taiwan; on the northern part of the

Lushan Formation and east of the Lan Yang Chi stream; about 20 km southwest of Ilan

STATUS
Power plant(s) on site

TEMPERATURE (°C)	60-300
INSTALLED CAPACITY (MWe)	4.5
POTENTIAL (MWe)	N/A

CHRONOLOGY
1973 - Geothermal exploration began by the Mining Research and Service Organization (MRSO), Industrial Technology Research Institute; began drilling 15 shallows test wells with depths of 161-501 m; penetrated aquifers with temperatures up to 175ºC (Chiang, et al., 1979).

1976 - Chinese Petroleum Corporation continued exploration; drilled more than 8 deep wells ranging from 1505 m to 3000 m (due to very rugged terrain, all the deep wells were drilled along the Qingshui River, the main geothermal manifestation area); encountered temperatures of 148.7-225ºC, flow rate of 370 tons/hr, and a flowing pressure of 8 kg/cm² (Chiang, et al., 1979).

October 1977 - Non-condensing 1.5 MWe plant installed under the auspices of the National Science Council for experimentation and demonstration (Cherng, 1979).

1978 - Roving bipole-dipole mapping method used to explore the area; revealed two obvious anomalies in resistivity and anisotrophy pattern — one located near the surface geothermal manifestation; the other to the northwest along the Lan Yang Chi stream (Lee, et al., 1980).

1979 - Large-scale and detailed well testing program began which included well production rates and well stream enthalpy measurements, pressure transient tests for drawdowns and buildups, temperature and pressure-depth survey, noncondensable gas content analysis, and interference testing (Chiang, et al., 1979).

March 1981 - Single-flash 3.0 MWe plant went online.

NOTES
There are a few hot springs in the area, but a large boiling spring (99ºC) is found in the middle of Lan Yang Chi stream.

Shallow drillings (< 500 m) done by the Mining Research and Service Organization (MRSO). Deeper drillings done by the Chinese Petroleum Corporation (CPC).

7 productive boreholes have been made, the deepest about 3000 m; recorded down hole temperatures as high as 300ºC.

Water has a high concentration of Na, HCO_3, and B as well as high HCO_3/Cl and B/Cl ratios which indicates a metamorphic origin (Cherng, 1979).

Sanshing	
LOCATION	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	N/A
CHRONOLOGY 1979 - New well drilled at Hanshi to test the possibility of hot water at depth.	
NOTES There are no surface manifestations at Sanshing.	

Tatun (Datong)	
LOCATION At the northernmost tip of Taiwan	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	120-293
INSTALLED CAPACITY (MWe)	0
POTENTIAL (MWe)	100-500
CHRONOLOGY	
NOTES Field lies in a volcanic region; exploration of a 1500 m-deep reservoir found temperatures of up to 293ºC; estimated generation capacity is 100-500 MWe (Cherng, 1979). More extensive development of this area has been suspended due to the corrosive effect of the acid sulfate-chloride hot water (Cherng, 1979). The steam alone is much less corrosive (Huang, 1978).	

Tuchang	
LOCATION In northeastern Taiwan about 30 km southwest of the	

Qingshui field	
STATUS Power plant(s) on site	
TEMPERATURE (°C)	40-173
INSTALLED CAPACITY (MWe)	0.30
POTENTIAL (MWe)	N/A
CHRONOLOGY 1985 - Experimental binary 300 kW plant went online.	

NOTES

Shallow drillings (< 500 m) done by the Mining Research and Service Organization (MRSO). Deeper drillings done by the Chinese Petroleum Corporation (CPC).

Many hot springs are scattered along the stream valleys; range of spring temperature is 40-98ºC (Cherng, 1979).

Water chemistry characterized by high content of sodium bicarbonate (> 2000 ppm), saturated silica, and low concentration of chloride and sulfate (< 50 ppm). At depth, dissolved carbon dioxide is relatively increasing in the thermal fluid (Chang and Cheng, 1981).

Field lies in a slate formation; reservoir temperature at 445 m is 173ºC.

U.S. Geological Survey reported a tentative estimated reservoir temperature of 190.6ºC. Na-K-Ca geothermometer (Fournier and Truesdell, 1973) shows a low temperature ranging from 150ºC to 170ºC (Cherng, 1979).

Conclusion

China

China's estimated power generation potential using geothermal resources is vast and untapped. While estimates ran the gamut from 200 MWe to over 10,000 MWe, the total estimated potential of the 254 sites included in the Database is a conservative 1588MWe. The actual potential is much greater because many of the 3,000+ hot springs scattered across the country have not yet been adequately evaluated.

In view of the remote locations of many hot springs in China, the lack of grid penetration, and the shortages of electricity nearby, special effort is needed to demonstrate the viability of very small plants with capacities of not more than 1-2 MWe (Allis et al., 1996). This is particularly true in the sparsely populated rural areas of western China where renewable and geothermal energy are important components of the GOC's "Strategy Plan for Developing the West Area of China" to bring electricity and economic development to the region.

The GOC's goal is to have 30 MWe of installed power generation capacity from geothermal resources by 2000, 40-50 MWe by 2005, and 75-100 MWe by 2010 (Zhai, 2000).

If China is to achieve geothermal development approaching this magnitude within the next 10-20 years, there needs to be a reassessment of all major hot spring occurrences, incorporating both economic criteria as well as realistic estimates of resource potential. Much of the resource data has already been collated by the provincial and state Geological and Mineral organizations, so a large part of this study would be office based, using in-house expertise. "Reservoir" temperature estimates need to be based on the TKMg geothermometer rather than the TNaK geothermometer (Giggenbach, 1988), and caution is needed when using the area of thermal manifestations as an indicator of reservoir area. The mass flow of hot water and apparent reservoir temperature will yield a heat output which is probably the best indicator of reservoir size (Allis et al., 1996).

Taiwan

Taiwan has an estimated geothermal power potential of 100-500 MWe (Lee, et al., 1981). With the privatization of Taipower and the power sector, the persistent power shortages, and the central government's new renewable energy development policy, now may be a good time for the further development of geothermal power generation in Taiwan.

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